THE IRON ORE DEPOSITS OF INDIANA.

By Chas. W. Shannon, Bloomington, Indiana.

A striking feature of present industrial conditions all over the civilized and commercial world is the great activity of the iron trade, which is now in the fourth year of its advance. Increase in production and consumption are reported everywhere, except in a few countries—Russia, for instance—where special conditions have checked prosperity.

Iron is the most useful, and, next to aluminum, the most abundant of metals, and is mined and reduced in almost every country in the world. In its native form iron is found chiefly in meteoric stones occurring with nickel and cobalt, and in certain ores of platinum, and is consequently of comparatively rare occurrence, but the so-called iron-ores, the oxides, sulphides, etc., are very widely distributed. Iron as an original constituent of igneous rocks is found in more numerous forms than almost any cther element. While the iron-ore deposits themselves contain much the higher percentage of iron, the main mass of the segregated iron is in the iron-bearing formations rather than in the iron-ores. The amount in the iron-ores is probably insignificant as compared with the amount in the iron-bearing formations. For example, in the Mesabi district in Minnesota, where the iron-ore deposits are larger than in any other region, Dr. Leith has calculated that in the part of the iron-bearing formation which is exposed at the surface, including no part which passes below the overlying slate, the amount of disseminated iron is probably one hundred times as great as that contained in the ore deposits, and the amount of this formation below the slates, in which there are no known ore deposits, is certainly many times, probably hundreds of times, that exposed. This calculation in reference to the Mesabi range shows how insignificant is the amount of iron ore in the ore deposit compared with the widely distributed lower grade products of the iron-bearing formations. Such formations are illustrated by the great Pre-Cambrian iron-bearing formation, of various Lake Superior localities; by the very extensive iron-bearing members and the ores of the Clinton Horizon of the Silurian; by the great iron-bearing horizon of the Carboniferous, and by the bog deposits of the Pleistocene.

There is a general impression that the world's supply of iron ore is approaching exhaustion. The principal argument against this is that improved methods of smelting will enable the lower grades of ore to be successfully used as a source of iron. The total production of iron ore for 1903 was 100,900,000 tons, and for 1905 was 147,500,000 tons. The basis of the trade is in the production of pig iron; and in the table below will be found the output for the first half of 1906 of the chief iron-making countries, which, together, furnish about 80 per cent. of the world's supply. The figures for Great Britain and our own county are in long tons of 2,240 pounds; those from Germany in metric tons of 2,204 pounds.

	1905.	*1906.*	*Changes.*
United States	11,163,175 T.	12,602,901 T.	I. 1,439,726
Germany	5,098,588 T.	6,073,936 T.	I. 975,348
Great Britain	4,621,600 T.	4,905,424 T.	I. 283,824
Total	20,883,363 T.	23,582,261 T.	I. 2,698,898 T.

The United States shows an increase of 12.9 per cent. over the first half of 1905, while the gain in Germany was 19.1, and of Great Britain 6.1 per cent. Germany shows the largest proportional increase. The total gain was 12.9 per cent.

Growth and Demand for Iron and Steel.—At the beginning of the last century comparatively little iron or steel was made in any country. There was but little demand for these products. In time railroads became, as they still are, the greatest of all the consumers of iron and steel; yet the Stockton and Darlington R. R. in England, the first railroad in the world to be built for general freight traffic and passenger travel, was not opened until 1825. The general use of iron and steel bridges and iron and steel steamships came later. Next followed the general use of steel in the construction of large buildings, especially those of great height. Last of all we have the steel car for freight purposes. These are the most prominent uses of iron and steel today, but simultaneously with the development of these leading uses there has been a constantly increasing use of agricultural machinery, textile machinery, mining machinery, electrical machinery, machine tools, iron and steel pipe, hardware, stoves, shovels, tin plates, wire and many other articles which are made wholly or in part of iron or steel.

The railroad era began at the close of the first quarter of the 19th century, but it was not until the third quarter of the century was well under way that an extraordinary demand for other than railroad purposes began to manifest itself in any progressive country. In our own country we built more miles of railroad in 1887 than any year before or since. The building of iron and steel vessels received a great deal of attention, particularly in Great Britain, in the third quarter of the century; but it was in the fourth quarter that the greatest progress was made in substituting iron and steel ships for ships of wood. As late as 1868 only five iron steamships were built in one year in this country for ocean service. We have since built over one hundred steel merchant vessels in one year and we have in late years built a magnificent fleet for the American navy, the frames and hulls and armor being of American steel. Armor plate for warships was not made in Great Britain until 1887. Iron and steel buildings already referred to, date from the third quarter, but they did not receive much attention from architects and builders until the fourth quarter, while steel cars were virtually unheard of until the century was nearing its end. The manufacture of tin plates was not introduced into the United States until 1890, except experimentally.

In a word, while the 19th century witnessed the development of the iron age, which was succeeded before its close by the steel age, it would be more exact to say that the last year of the first quarter of the century when the railroad era began, witnessed only the beginning of this development, and the last quarter has seen its ripest fruits, even the last few years of the last quarter.

The rapid growth of the world's iron and steel industries in the 19th century, particularly in its last quarter, could have been possible only by substituting improved methods of manufacture for the slow and expensive methods that were in use at its beginning. The railroads of today could not have been supplied with one-half the rails they needed, indeed the half of these roads would never have been built, if the invention in 1855 of the Bessemer process for making steel had not resulted in giving to the world steel rails which would last longer and could be more cheaply and rapidly made than the rails made of puddled iron. Nor could the steel that is used today in such large quantities for various structural purposes, bridges, buildings, ships, cars, etc., have been made at all but for the Bessemer process and its companion, the Siemens open-hearth process, the latter process dating from 1864. Nor could the pig iron that has been required by the Bessemer and open hearth processes have been supplied, not even the half of it, if reliance had been placed upon the small furnaces, the lean ores, and the charcoal fuels that were in common use less than 100 years ago.

The present wonderful development of the world's iron and steel industries is, therefore, due to the abundance of iron ores and mineral fuel which has been so easily obtainable.

Summary.—The aggregation of large iron ore mines and the control of many prominent producers by consolidated interests has attracted attention to the iron ore reserves of the country, with the effect of awakening some anxiety as to a sufficiency for the future, but an investigation will satisfy an observer that such anxiety was unfounded.

Most of the well-known worked mines, or those producing the best or most desirable grades of ore, which are conveniently accessible for existing blast furnaces, have been secured by the larger steel plants. There are, however, important mines owned or operated independently of consolidation.

Material advance in the price of the mineral will encourage the development of mines which are inactive or operated upon restricted scale, and also the opening of deposits heretofore unworked. Such a condition will also secure the transportation of ores from localities now considered too remote for economical use.

A decided advance in selling prices will also stimulate larger importations of ores from foreign countries, upon which a duty of about 40 cents per long ton is levied.

The known existence of iron ores in all the States of the Union has been reported. In some the mineral is lean or impure or in such thin or widely distributed bodies as to discourage operation, but there are many iron ore deposits of excellent composition existing in large quantities which have as yet been undeveloped, and there are other deposits exploited in former years and found to be limited, which under advanced conditions could be revived.

Immense bodies of magnetites in the East can meet a heavy demand for ore, and the reduction by roasting of sulphur in such as need it, or of phosphorous and gangue material by concentration, can be carried on profitably if the selling prices of ores are much advanced.

It is not improbable that large deposits of titaniferous magnetites may be brought into demand if the supply of ores free or nearly free from titanium is restricted. Many deposits of brown hematite and red hematite ores, which have been worked on a small scale, can be augmented, and the output be cheapened, materially swelling the country's total.

The basic treatment of iron, which is advancing rapidly, may also be expected to remove the limitations which have been placed upon ores for steel productions.

In the central and western portions of the country there are important deposits of excellent iron ore which await the extension of the iron and steel industry or of transportation facilities, and if these ores can not be conveyed to existing furnaces the plants will be placed nearer to the ores as rapidly as the country's demand makes such a course advisable.

Iron and concrete must largely take the place of our rapidly disappearing forests, and in consequence the consumption will undoubtedly increase at a greater rate than in the past. Low grades, as well as inaccessible deposits like those of Utah and possibly Alaska, will be in demand, and very likely this country may be forced to draw upon Mexico and South America for part of its ore supply before the middle of the present century, but the consumption would be hard to predict.

The World's Production of Iron Ore.

The latest authentic statistics at hand of the production of iron ore in all countries are for the year 1904. In the list below the countries are named in the order of their production: United States, Germany, Great Britain, Spain, France, Russia, and Finland, Sweden, Austria-Hungary, Cuba, Algeria, Italy, Greece, Canada, Belgium, Australasia, India, Japan, New South Wales and New Foundland, with all other countries producing about 1,400,000, or a little more than one-half as much as Austria-Hungary.

The United States has far surpassed any other country, the production now being almost twice that of Germany, and three times that of Great Britain. At least 25 of the States and Territories may be classed as iron ore producers. No complete report has yet been published for the last two years to show the rank of the various States in the production of iron ore, but from information given out there will be but little if any change in the order of importance. Minnesota.—This State leads in the quantity of ore mined. Much has been said in regard to the early exhaustion of the iron ore supply of the Lake Superior district, but in Minnesota alone, in the Mesabi Range, there are reported to be known and explored reserves approximating 500,000,000 tons, practically twice the combined shipments from all the ranges of the Lake Superior region since 1854. Michigan takes second place and nearly all the ore is red hematite and is obtained from the Marquette, Menominee and Gogebic ranges. Alabama, as third in rank, contributes three varieties of ore—red hematite, brown hematite and magnetite. New York.—Activity in the Port Henry and Lake Champlain districts have advanced the State to fourth position. Large cargoes of ore for the manufacture of basic pig, were exported to Germany. Virginia and West Virginia.—The chief ore of these States is brown hematite; small quanties of red hematite and magnetite were also obtainable. Tennessee produces both brown and red hematite. New Jersey produces chiefly ores of the magnetite variety. Wisconsin shows a steady advance, as the Baraboo district is extending its production nearer first place. Pennsylvania.—This State in late years has shown a constant decrease in its production of iron ore. It produces red and brown hematites and magnetite. Georgia is a producer of brown and red hematites. It has declined somewhat in the last year or two. Colorado.—This State furnishes brown and red hematite. But the production has declined on account of the decrease in the brown hematite variety. Montana, Nevada, New Mexico, Texas, Utah, and Wyoming are small producers of magnetite and red and brown hematites. New finds are reported in Utah. Other States.—Of the remaining States contributing small amounts, Connecticut furnishes brown hematite; Missouri, red and brown hematite; Maryland, brown hematite and carbonate; North Carolina, brown hematite and magnetite, and Ohio, carbonate and brown hematite ores.

Some of the famous and extensive deposits will be described in the following pages to show the extent of the iron ores, and from which we may be able to determine to what degree lower grade ores and inaccessible deposits will be utilized in the near future.

In the United States.

Production and Development.—Most of the iron ore reduced in the United States, which yields about one-fifth of the world's supply, comes from the Lake Superior region, from the Appalachian region and the Ozarks, but great quantities of ore exist throughout the west.

In 1866 less than 3,000,000 tons of iron ore were mined in this country. In 1870 the output was 3,031,891 tons; in 1880 it had reached 7,120,362 tons; in 1890 the total output was 16,036,043 tons; in 1900 it had reached 27,553,161 tons. Five years later, 1905, the total output was 43,000,000, and in 1906 a total of 49,-000,000 tons was reached. This practically represents an increase in the past forty years of about 1,300 per cent. But even more impressive than the marvelous development of the iron ore industry in this country are the improvements made in the methods of mining and handling the iron ore and its products. Formerly practically all mining was done by manual labor, while today in our hard ore mines a compressed air drill turns out as much ore as was formerly mined by nine men, while in the soft ore mines a steam shovel, with three or four men, will mine and load a car in five minutes. The use of explosives, the loading and unloading machines at the great ore docks, the more extensive use of waterways and the development of water powers, and the transportation facilities of our railroads and the saving in fuel charges have all contributed largely to reduce mining costs. Impure and lean ores, especially the magnetites of the East, have been made available and very rich in yield of metallic iron by magnetic separation (this process is briefly described) and a large proportion of the gangue is removed without the use of fuel. In the early days of the iron industry the average car load was less than 15 tons, now cars are built to carry over 50 tons. Before 1870 the Lake Superior ore boats did not reach a capacity exceeding 1,000 tons, while today boats are built to carry 10,000 tons.

Exports and Imports.—Exports of iron and steel and of machinery from the United States for the ten months ending October 31, 1906, are valued by the Bureau of Statistics of the Department of Commerce and Labor as follows:

	1905.	*1906.*	*Changes.*
October	$12,673,947	$15,910,437	I. $3,236,540
Ten months	115,596,224	142,609,320	I. 27,013,096

The increase for October was 25.5 per cent.; for the ten months it was 23.4 per cent. The leading item of the iron and steel exports for the ten months were in long tons.

	1905.	*1906.*	*Changes.*
Pig iron	41,212 T.	65,463 T.	I. 24,351 T.
Billets, ingots and blooms	179,880 T.	180,632 T.	I. 752 T.
Bars	44,661 T.	72,094 T.	I. 27,433 T.
Rails	249,941 T.	273,009 T.	I. 23,068 T.
Sheets and plates	59,780 T.	90,673 T.	I. 30,893 T.
Structural steel	63,401 T.	93,460 T.	I. 30,059 T.
Wire	110,244 T.	144,193 T.	I. 33,949 T.
Nails and spikes	40,828 T.	52,731 T.	I. 11,903 T.

The large exports of rails this year were to South America, 101,357 tons; Canada, 65,237 tons; West Indies, 29,760 tons; Japan, 20,011 tons; Mexico, 19,145 tons.

Iron and Steel Imports.—Imports, including machinery, into the United States for the month ending October 31, are valued by the Bureau of Statistics as follows:

	1905.	*1906.*	*Changes.*
October	$2,225,194	$3,407,763	I. $1,152,569
Ten months....	21,820,949	27,784,650	I. 5,963,701

The increase in October was 51.1 per cent.; for the ten months it was 27.3 per cent. The more important item of the imports for the ten months were in long tons.

	1905.	*1906.*	*Changes.*
Pig iron	170,891 T.	265,665 T.	I. 94,774 T.
Scrap	12,604 T.	11,203 T.	D. 1,401 T.
Ingots blooms, etc.	11,501 T.	17,067 T.	I. 5,566 T.
Bars	29,186 T.	28,754 T.	D. 432 T.
Wire rods	14,413 T.	15,080 T.	I. 667 T.
Tin plates	58,788 T.	48,846 T.	D. 14,942 T.

The chief points are the large comparative increase in pig iron and the decrease in tin plate.

Exports and imports of the iron ore in the United States for the ten months ending October 31 are reported as follows in long tons:

	1905.	*1906.*	*Changes.*
Exports	179,919 T.	256,384 T.	I. 76,465 T.
Imports	709,766 T.	908,366 T.	I. 198,600 T.

Most of the exports were to Canada. Cuba furnishes the greater part of the imports, but some ore came from Canada and a little from Spain.

Imports of manganese ore for the ten months were 218,225 tons in 1905 and 185,281 tons in 1906, a decrease of 32,994 tons. This ore came from Russia, India and Brazil.

Summary for 1906.—The actual production of pig iron in the United States for the first half of 1906 was 12,602,901 long tons, being a gain of 1,439,726 tons, or 12.9 per cent., over the first half of 1905, and 6.5 per cent. over the last half. The amount made in the half year was greater than that for any entire year prior to 1889. These results emphasize the continued increase in the use of steel.

For the half year 92.3 per cent. of the iron produced was made with coke as fuel. This would be increased to over 95 per cent. if allowance were made for the coke used by the anthracite furnaces, nearly all of which mix some coke with their coal. The total number of furnaces in blast during the half year was 323 and the average 318, showing an average of 39,632 tons of pig iron made per active furnace. The total number of blast furnaces under construction August 1, 1906, was twenty-one, the total production capacity being 2,642,000 tons pig iron and 20,000 tons spiegeliesen yearly. Four of them at Gary, Indiana, with a capacity of 150,000 tons each.

The total make of rails was 3,372,257 tons, of which 3,188,675 tons were made from Bessemer steel; basic open hearth steel furnishing the balance. Iron rails have almost disappeared, only 318 tons having been made in 1905, and those were mine rails of light section.

For opening 1907 deliveries coke is very scarce and prices remain high, being $6.65@7.00 for the best Connellsville, with Virginia cokes 25@50c lower.

Manufacture of Iron.

History.—The increasing use of iron is a prominent characteristic of the present age, and every day sees some new application in the arts of life. Although the most useful of metals, it was not the first known. Difficulty in reducing it from its ores would naturally make it a later acquisition than gold, silver or copper.

We are informed by the Roman historians that this metal was employed by the ancient Britons for the manufacture of spears and lances. The Romans, during their occupation of Britain, manufactured iron to a considerable extent, as is evidenced by the cinder heaps in the forests of Dean and other places. The process then in use left so much iron in the cinder that those of Dean forest furnished the chief ore supply to twenty furnaces for between two hundred and three hundred years. In those early times the iron ores were reduced in a simple conical furnace, called an "air-bloomery," erected on the top of a hill, in order to obtain the greatest blast of wind. The furnaces were subsequently enlarged and supplied with an artificial blast. Charcoal was the only fuel used in smelting until 1618, when Lord Dudley introduced coal for this purpose, but the ironmasters being unanimously opposed to the change, Dudley's improvement died with him. It was not reintroduced until Abraham Derby, in 1713, employed it in his furnace at Coalbrook Dale. But as this method was not properly understood the production of English iron declined with the change of fuel, till, in 1740, it was only three-fourths what it had been. About ten years after this, however, the introduction of coke gave renewed vigor to the iron trade, and then followed in rapid succession the great improvements in the manufacture, which gives to the history of iron its greatest interest. The introduction of Watt's steam engine in 1770, the processes of puddling and rolling invented by Henry Cort in 1784, and the employment of the hot blast by Neilson of Glasgow in 1830, have been each of inestimable service. The greatest improvement introduced into iron manufacture in recent years is the "Bessemer process" for the production of steel, patented in 1855. The "Siemen's-Martin" method of making steel has also of late come into extensive use. And an important new process has been patented by S. G. Thomas.

Until recently, when it has dwindled down to an insignificant industry, iron ore was reduced direct to iron, with the use of charcoal as a fuel, in forges called Catalan forges, from the district in Spain where they originated.

One of the principal seats of the industry in this country was in the Adirondack Mountains, in New York, where the process still survives in a few isolated localities.

Smelting.—The greater portion of iron is produced by smelting in a blast furnace, the product being pig iron, an alloy of iron, carbon and silicon, containing generally some sulphur and phosphorus, often manganese, and occasionally copper in notable quantities. In this process the ore is deprived of its oxygen by the action of incandescent carbon, and the hot reducing gases resulting from its combustion brings it to a liquid mass which is either allowed to run into ladle cars to be hauled by locomotives to adjacent steel works, or puddling mills, or it is allowed to flow into a series of sand molds from which it is taken when cool, this product being commercially known as "pig" or "cast" iron; as such, pig iron can only be used in the manufacture of castings. Hence by various processes it is converted into malleable or wrought iron and steel. It is possible to produce malleable iron directly from the ore without this process of smelting in the blast furnace. This direct, as distinguished from the indirect, process of first making pig iron has always possessed particular attraction for inventors and experimenters. Many have struggled with the problem, but failed to reach commercial success. The basis of all these efforts is the facility with which iron oxides are reduced at moderate temperatures when in contact with carbon in some form.

Blast Furnaces.—Practically all the iron produced in the leading manufacturing countries, as has been stated, is obtained by the indirect process, the first operation being the smelting of the ore in a blast furnace. The manufacture of commercial iron consists chiefly in the reduction of its oxides, such as hematite, Fe_2O_3; magnetite, or loadstone, Fe_3O_4; and limonite, Fe_2 $(OH)_6$ Fe_2O_3. Blast furnaces vary in size and shape; the size depending largely upon the kind of fuel to be used—a coke-fed furnace being larger than one in which soft coal is used. The furnace is a vertical shaft, cylindrical and in horizontal section, widening from the top downward to near the bottom, ranging in height according to local circumstances, from sixty to ninety feet, and from twelve to twenty feet in diameter at its widest part. The body is formed of wrought iron plates, riveted together, forming a shell, which is lined with the most refractory variety of fire brick. This body or stack is supported on a cast iron ring resting on columns. Below the furnace is contracted to form the hearth in which the molten metal and slag and cinder accumulates. At a given distance above the bottom are openings, through which water-jacketed pipes are introduced, called "Tuyeres." Through these air or "blast" is blown by blowing engines, the blast being conducted to the tuyeres from a pipe which encircles the lower part of the furnace, and from which branches lead to the tuyeres. The materials are charged at the top, which is closed by a bell lowered by a special appliance, whenever ore, fuel or flux are to be allowed to drop into the furnace. The top is closed in order to divert laterally the gases produced in a large pipe called the "down comer." The gas is utilized in heating hot blast stoves and in raising steam to supply blowing engines and elevators with power.

In modern blast furnaces, those parts which are exposed to the greatest heat are saved from rapid destruction by a system of water cooling, a number of appliances being used. The molten iron which accumulates at the bottom of the furnace is tapped off, while the cinder, which constitutes the earthy impurities of the ore, and the ash of the fuel with the flux added, is allowed to flow off continuously at a somewhat higher level. Being lighter it floats on the iron.

In the blast furnace there are two currents, traveling in opposite directions and constantly acting on each other—the ascending current of gas and the descending current of ore, fuel and flux. The effect of the highly heated blast (reading 1,000° Fahr. and upward, with modern hot blast stoves) is to produce carbonic acid at the level of the tuyeres where it comes in contact with descending incandescent fuel. This carbonic acid in ascending is reduced to carbonic oxide by the excess of carbon and becomes the active agent in reducing the oxide of iron to metallic iron. The latter in contact with highly heated carbon forms an alloy, melts and collects in the hearth, constituting "pig iron."

The ascending current of hot gas heats the descending column of solid materials, which come down as the lower parts of the column are melted and tapped off. The result is that from the white heat attained at the tuyeres and for some distance above them, the temperature gradually lessens until near the top it is moderate.

Since all iron ore contains varying quantities of impurities and accessory materials, notably silica, aluminum, magnesia and lime, and the fuel carries varying amounts of ash, their removal is affected simultaneously with the reduction of the ore by melting into a homogeneous mass the cinder. In order to produce a cinder whose composition is such that it forms at the proper temperature, it is necessary in the majority of cases to add limestone.

The ore, limestone and fuel are charged at the top of the furnace in alternate layers, the "stock," as it is called, being hoisted to the top of the furnace either in elevators or on inclined planes. The cinder is generally allowed to flow into boxes mounted on cars and is easily disposed of—casting it liquid or throwing it when cold on adjoining territory. It is used as road ballast, in the making of cement, in glass making and in the production of slag-wool.

Fuel consumption is one ton of coke to one ton of pig iron produced, i. e., between 1,000 and 1,500 tons per week for each coke furnace. In recent years the blast furnace has also been used for the manufacture of ferro-manganese, ferro-chromium, ferro-silicon and other alloys.

Transformation of Pig Iron Into Wrought Iron and Steel.—Pig iron, by various processes, is converted into wrought iron and steel. The pig or cast iron is hard and comparatively brittle and can be readily fused at a high temperature, and may be moulded into solid forms by casting, and in modern iron works forms an intermediate product in the manufacture of the other classes. According as the metal may be best adapted for founders' or forge masters' use it is distinguished as forge or foundry pig.

Cast iron, as the crudest, cheapest and most fusible, is used for the heavy portions of engineering work, such as bed plates for machines, cylinders, columns, cisterns, low-pressure boilers, water and gas pipes, rollers, girders and the like. A large quantity is consumed in the manufacture of "hollow wares," which includes pots, pans and other cooking vessels. For all kinds of ornamental objects, also, it is almost exclusively used, because here its property of being readily cast into molds gives it a great advantage on the score of cheapness.

(1). *Wrought or Malleable Iron.*—This is the nearest approach to the chemically pure metal that can be obtained on the large scale. Wrought iron has a clear gray color and a specific gravity of 7.7-7.8. It is softer than cast iron or steel, and extremely tenacious and may be drawn into the finest wire or hammered or rolled into sheets as thin as paper. When two pieces heated to redness are placed in contact and hammered they unite, practically forming one piece; this process is known as welding. When heated and suddenly cooled it retains its softness. The quality of the iron is greatly influenced by the presence of phosphorus and sulphur. Even .01 per cent. phosphorus renders the iron brittle when cold; it is then termed "cold-short," and an equally small amount of sulphur makes it brittle when hot, so that it will not weld into a close joint, but splits and crumbles and is said to be "hot," or "red-short." The presence of any foreign body, such as sulphur, phosphorus, carbon, silicon, copper, oxygen, etc., increases the difficulty of welding. To insure a good weld the surfaces must be clean and the metal at a white heat. Malleable iron is largely employed in manufacture of hardware, such as locks, hinges, bolts, nails, screws, keys, wire, etc., and the so-called tinplate, which is merely sheet iron dipped in melted tin. It is also much used for roofs and bridges of large size and is the mainstay of the railways and the electric telegraph and has almost displaced timber as a material for ships. Rolled armor plates for warships are now made of malleable iron from five to twenty-two inches thick. When iron is exposed to moist air it readily rusts, or oxidizes, so it is often coated with some substance to prevent this, such as tinning, galvanizing and painting.

(2). *Steel.*—Pig iron is the raw material from which steel is made. Steel possesses several valuable properties which do not belong to either cast or wrought iron, but it also partakes of some of the properties of both. It is harder, denser, and whiter in color, is more elastic, takes a higher polish and rusts less easily. It is of a finely crystaline structure, with a specific gravity of 7.6-7.8. Steel may be made in two ways: By increasing the carbon in wrought iron to between .6 and 1.5 per cent., either by adding carbon directly to it or by adding pig iron until the carbon is sufficiently increased. The second way is to remove the carbon from the pig iron.

Pig iron is treated in the Bessemer converter for the production of Bessemer steel; in the Siemens' furnace for Siemens' steel, and melted in a cupola for foundry purposes. The "Bessemer process," invented about 1855, is successfully and largely used in the making of steel. The first stage is effected through the Bessemer converter, made of wrought iron and lined with an infusible material. Into this converter from five to ten tons of molten pig iron are poured and a powerful blast of air is blown through the molten iron until the carbon and silicon is removed by oxidation, and then introducing into the melted iron a given quantity of spiegeleisen, containing a known percentage of carbon. The steel is then poured into molds and allowed to cool. These are the "steel billets" of commerce. Many of the converters are lined with dolomitic limestone, and a quantity of lime is added to the molten iron, and practically all the phosphorus is taken up by the lime and the lining of the converter. Bessemer's invention revolutionized the manufacture of steel. Now ten tons of crude cast iron may be converted into good steel in less than thirty minutes in a single converter. Such steel is extensively used in rails, bridges and boilers.

The Siemens' regenerative gas furnace is now much used for the making of steel. No other furnace can be compared with it in respect to economical consumption of fuel; almost any kind of fuel, however poor, may be used for the gas producers, which are connected by means of a pipe with the regenerators. The furnace consists of two parts: one of these contains the "regenerators," the other, which may be near or some distance away, contains the "gas-producers," or source of the heat. In the regenerative portion there is a melting hearth or bed. Immediately below this hearth there are two pairs of arched chambers filled with fire bricks placed sufficiently far apart to let air or gas pass between them, and at the same time expose a large surface to the heat from the gas-producers. One pair of these chambers communicates by separate flues with one end of the hearth, the other pair with the opposite end. The furnace being in operation, while the gas and air are being admitted to the hearth through the left pair of these chambers, the highly heated products of combustion pass through the open brick work of the corresponding pair on the right before reaching the chimney; thus what would pass up the chimney as waste heat in an ordinary furnace is absorbed by the bricks of the regenerators. After a given time—usually from thirty to sixty minutes—by means of suitable pipes and valves the current is reversed. Gas and air are now sent through the freshly heated pair of generators, while the "waste heat" in turn passes into the other pair, thus hot currents of gas and air in suitable proportions are always reaching the hearth, where combustion is effected at a very high temperature.

The pig iron produced in the blast furnace is carried in large ladle cars, in a molten condition, to the converters; there it is blown and the liquid steel cast in "ingot" molds. The blocks of steel, as soon as the outer crust is sufficiently cooled to allow their removal from the molds, are put into soaking pits. When their heat has been equalized they are carried to rolling mills where they are rolled direct into steel rails, plates, beams, etc. In the production of Bessemer steel, Pennsylvania is credited with over one-half of the output. This State also leads all the States in the production of open hearth "ingots," in crucible steel, in rolled iron and steel.

The modern blast furnace, with its immense blowing engines, its hotblast stoves, its rich ores and excellent coal to smelt them, has been a powerful factor in the present marvelous development of the world's iron and steel industries.

Chemistry of Iron.—Iron has for its symbol, Fe., from the Latin Ferrum. Its specific gravity is 7.3 to 7.8. Pure iron may be obtained by reducing peroxide by means of hydrogen gas and heat, when it is obtained in the form of a fine black powder, or by heating the protochloride in a glass tube through which a current of dry hydrogen is passed, the iron is deposited as a glistening mirror on the glass. Thus chemically pure iron is of very little general interest, and, practically speaking, may be said to be of no commercial value. But on the other hand very small traces of foreign elements exert a very marked influence on the metal, and it is these small, and in many cases unnoticed, differences of composition that render so many points in the chemistry and practical working of iron obscure and difficult to be understood. When it is considered that the investigation of such problems calls for researches involving the utmost refinements of analytical chemistry, it is not remarkable that contradictory statements and opinions still abound on many points of the chemistry of iron making.

The melting point of pure or even ordinary malleable iron has not been determined with certainty. According to some it lies between 1500° and 1600° centigrade, while others place it as high as 2100°. Pure iron is susceptible of being magnetized to a much higher degree than steel, but unlike the latter, it does not retain its magnetism when the exciting cause is removed.

The affinities of iron for most of the non-metallic elements are very powerful. The chief of the iron compounds are (a) Oxide of Iron. Iron forms definite compounds with the oxygen, viz: (1) the protoxide, FeO, which is the base of the green or ferrous salts of iron; (2) the sesquioxide or peroxide Fe_2O_3, which is the base of the red or ferric salts; (3) the black or magnetic oxide, Fe_3O_4, which is regarded by some chemists as a compound of the two preceding oxides, and (4) ferric acid, FeO_3. The protoxide cannot be obtained in an isolated form, but it forms the base of various ferrous salts and combines with water to form a hydrate, $Fe(OH)_2$. The most important protosalts of iron or ferrous salts are the carbonate, the sulphate, the phosphate and the silicate. Carbonate of iron, $FeCO_3$, exists naturally in various minerals and may be obtained artificially by precipitating a soluble protosalt of iron with carbonate of potash or soda, when the carbonate falls in white flakes. On exposure to the air it absorbs oxygen and gives off carbonic acid and is thus converted into the hydrated sesquioxide. Sulphate of Iron, $FeSO_4+7H_2O$, is obtained by the solution of iron or its sulphide in dilute sulphuric acid; in the former case there is an evolution of hydrogen and in the latter of hydrogen sulphide. The reactions are expressed by the following equations:

$$Fe+H_2SO_4=FeSO_4+H_2.$$
$$FeS+H_2SO_4=FeSO_4+H_2S.$$

By evaporation of the solution the salt is obtained in clear, bluish-green rhomboidal crystals, containing seven equivalents of water. This salt is commercially known as copperas or green vitriol. Phosphate of iron is obtained by precipitating a solution of protosalt of iron with phosphate of soda, when a white precipitate of phosphate of iron is thrown down. All these salts, especially the carbonate and sulphate, are extensively used in medicines. Silicate and phosphate of iron occur naturally in several minerals. The peroxide of iron, known as sesquioxide, red oxide, or ferric oxide, is used for polishing glass, jewelry, etc., and is also used as a pigment. Ferric acid has not been obtained in a free state, and is only known as a constituent of certain salts. Haloid Salts of Iron—the chlorides—viz.: a protochloride, $FeCl_2$, and a perchloride, Fe_2Cl_6. The tincture of the perchloride is perhaps more generally employed in medicine than any other preparation of this metal. (c) There are probably several sulphides or sulpurites of iron.

The ordinary sulphide is a protosulphide, FeS. It occurs in small quantities in meteoric iron. It may be obtained artificially by the direct union of the two elements at a high temperature. It is insoluble in water, but in moist air becomes rapidly oxidized into protosulphate of iron. With acids it develops sulphureted hydrogen. The bisulphide of iron, FeS_2, is the iron pyrites of mineralogists, and the Mundic of commerce. Under the latter name it is used extensively in the preparation of oil of vitriol. There are also other sulphides of less importance.

The chemical changes which take place in the preparation of iron are essentially reduction and oxidation, the reduction of the iron oxide to metallic iron, and the oxidation of the carbon to carbon-dioxide. The nearly complete combustion of the carbon in the crucible produces metallic iron, carbon-dioxide, and carbon-monoxide.

$$Fe_2O_3+C_2=2Fe+CO+CO_2.$$

The gases pass up through the strata of hot carbon and ore, where the carbon-dioxide is largely reduced to carbon-monoxide. The carbon-monoxide is combustible, uniting with oxygen to form carbon-dioxide. It is, therefore, a reducing agent. Since the oxygen from the tuyeres has been largely combined in the crucible, the carbon-monoxide must draw its oxygen from the ore. It is consequently active in reducing the iron to the metallic state. This may be expressed by the following equation:

$$Fe_2O_3+3CO=Fe_2+3CO_2.$$

Many things relating to the chemistry of iron are here omitted and will be found under other topics where they are necessarily mentioned.

Minerals Used as Ores of Iron.—In the United States the minerals smelted for iron are, in order of quantity used, hematite, limonite, magnetite and siderite. Goethite and turgite are commercially included with limonite under the name brown hematite and more or less ilmenite is melted with other ores. The residues from the roasting of pyrites are sometimes used as a source of iron, but not in this country. The mineral franklinite, after treatment for zinc, and certain manganiferous hematite and siderites, are smelted and yield "spiegeleisen," an alloy of iron and manganese, used as a source of carbon and manganese in the manufacture of steel.

The varieties of ore and the district in which they are found may be given as follows:

1. Red hematite, being all anhydrous hematite, although known by various names, such as red hematite, specular, micaceous, fossil, slate, iron ore, martite, blue hematite, etc. The red hematite class contributes about three-fourths of the total of iron ores produced. It is blackish red to brownish red in color, or a steel gray color, assuming a red tint in thin fragments and when it is scratched. Its symbol is Fe_2O_3, and it contains, when pure, 70 per cent. iron. It usually carries silica, manganese and some phosphorus as impurities. Minnesota is the largest producer of red hematite ores, Michigan follows very closely, while Alabama ranks third.

2.—Brown hematite includes the varieties of hydrated sesquioxide of iron, recognized as limonite, goethite, turgite, bog ores, pipe ores, etc. Brown hematites are distinguished by their brown or yellowish brown color. When pure it contains about 60 per cent. of iron and 14.4 per cent. water. It contributes about one-seventh of the total production. Virginia and West Virginia lead as brown hematite sources of supply, Alabama being second and Colorado third. The bog iron ore (described more fully in the following pages) is a variety of brown hematite, usually containing phosphorus, and occurs in marshy districts and recent formations.

3.—Magnetite includes the ores in which the iron occurs as magnetic oxide and including some martite, which is mined with the magnetite. Its symbol is Fe_3O_4, containing, when pure, 72.4 per cent. iron. It is a black mineral with metallic luster, strongly attracted by the magnet (no other black mineral is strongly attracted by the magnet) and occurring in all conditions from loose sand to compact, coarse or fine-grained masses. It is highly valued for its purity. It makes up about 10 per cent. of the iron ore mined in America, being obtained especially from the States of Pennsylvania, with the greatest amount, and New York and New Jersey indicating a close contest for second place, and Michigan coming in for fourth place. Smaller amounts are obtained elsewhere and it is present in many localities. In this country loadstones are obtained mainly from Magnet Cove, Ark. Whole mountains are made up of this mineral in Sweden and it is practically the only iron ore mined in that country.

4. *Carbonate, or Siderite.*—These are the ores which contain a considerable amount of carbonic acid. When found in a comparatively pure or crystallized state it is known as spathic or sparry ore, but when impure and earthy as clay, or clay-band ironstone, or black band. It is found in Ohio, Maryland, New York and in the coal regions of Pennsylvania, Virginia and Tennessee.

It is used as an ore of iron and when high in manganese it is used for the manufacture of spiegeleisen, but forms only a little over one per cent. of American iron ore. The ore mined from deposits in the U. S. is usually subjected merely to a rough hand-sorting to get rid of accompanying rock or of lean ore, so that the shipping ore is carried up to or above a specified minimum iron content. In the case of brown ores, washing must often be resorted to in order to take out the clay. During the past few years, however, particularly since the prejudice against the use of fine ore in the blast furnace has lost much of its potency, lean iron ores are crushed and concentrated to remove the accompanying gangue. This has been particularly the case with magnetites, recent inventions having improved machinery for separating by magnetism the particles of magnetite ore from the non-magnetic rock or gangue intermingled with them. All carbonate ores, and those ores of other classes, particularly magnetites, which carry sulphur, are "roasted," a simple heating process, the object of which, in the first class mentioned, is to expel the carbonic acid, while the latter is to attain a partial elimination of the sulphur. Incidentally, the roasting, particularly in the case of magnetites, tends to put the ore physically and chemically into a condition better suited for its subsequent reduction to metallic iron in the blast furnace. Roasting is now generally performed in the kilns, which, when they are located in the proximity of blast furnaces, are often heated with the waste gas from the latter.

Minerals Used for Production of Acids.—(a) Sulphur-pyrite, and, to a large extent, marcasite and pyrrhotite, are very extensively used in the manufacture of sulphuric acid. The sulphides are burned in furnaces with grates, and the gases are converted into sulphuric acid. The residues, in addition to iron, frequently contain copper, nickel or gold, and these are usually extracted later. The largest deposits working in the United States are in Massachusetts, New York and at several localities in Virginia; considerable deposits are also found in several other places. Pyrite is being formed today by the action of hydrogen sulphide of thermal springs upon soluble iron salts. It has been developed in many rocks by the action of water on iron salts in the presence of decomposing organic matter. It may be, also, of igneous origin. It is found in rocks of all ages, associated with other metallic sulphides and with oxides of iron. It readily oxidizes and decomposes, forming sulphate of iron and sulphuric acid, thus acting as a vigorous agent in the decomposition of rocks. The final results are usually limonite and sulphates of calcium, sodium, magnesium, etc. Few minerals are of such general and widespread occurrence.

(b) *For Arsenic.*—The mineral arsenopyrite is the chief source of arsenic of commerce and occasionally contains enough gold or cobalt to pay for extraction. It is found chiefly in crystalline rocks with other metallic sulphides and arsenides. Throughout the Rocky Mountains it is a common mineral; it is also found in New England.

(c) *For Chromium.*—Practically all the chromium compounds derive their chromium from the mineral chromite, very little of which is now mined in the United States. The most important compounds manufactured are potassium bichromate used in calico printing, oxidizing rubber, bleaching indigo and in manufacturing the chrome paints and matches; potassium chromate used in the manufacture of aniline colors, etc., and ferro-chromium, which added to steel, produces the tough alloy known as chrome steel.

(d) For Tungsten.—Tungsten and the tungstates are extracted from wolframite and scheelite. The world's product is not more than 600 to 700 tons, and is chiefly employed in the manufacture of crude tungsten for tungsten steel and sodium tungsten for rendering fabrics non-inflammable.

The Lake Superior Region.

The Lake Superior region is by far the most important single factor in the world's production of the most useful of all metals. This region includes the States of Minnesota, Wisconsin, Northern Michigan and the provinces of Canada bordering on Lake Superior.

The iron ores of the Lake Superior region all occur within or are associated with certain formations which have been called the iron-bearing formations. The cherty iron-bearing carbonates are the chief original sedimentary rocks of the iron-bearing formations. These are the rocks from which the other varieties of the iron-bearing formations and the iron ores have been mainly produced by various metamorphic and sedimentary processes. The iron-bearing carbonates vary from nearly pure siderite to dolomite. Between these different minerals gradation varieties exist. In the Mesabi district it has been held that the source of the iron can be traced to glauconite. But the work done by the United States Geological Survey seems to indicate that hydrous ferrous silicate and iron carbonate are the important sources of iron ore in that district. Analyses by Sleiger show that iron silicate is not glauconite, as it contains no alkali. In the Michipicolei district of Ontario, pyrite and marcasite occur within the original iron-bearing carbonate and with quartz in associated rocks. Pyritic quartz rocks also occur in the Vermillion district in great quantities. The iron sulphide to some extent has undoubtedly been a source of the ores. But it still remains true that the iron-bearing carbonates are the dominant original sedimentary rocks out of which the iron-bearing formations and ore bodies have been produced.

The Lake Superior ores are of higher grade than those from other parts of the United States and the actual amount of iron ore produced in the lake region is about four-fifths of the total of the United States. The total product from the Lake Superior region since shipment first began in 1850, to 1900, inclusive, was 171,418,984 long tons, but it was not until 1860 that the shipments of Lake Superior ore annually exceeded 100,000 tons. Coke did not exert an appreciable influence upon manufactured pig iron in this country until after 1850. These dates show how late in the last century we began to utilize the raw materials that now have a world-wide reputation. There is apparently no limit to the supply of rich iron ores in the Lake Superior region and elsewhere in this country. The Vermillion and Mesabi ranges alone, in 1906, produced a total of 25,500,000 tons.

The iron ores of the Lake Superior region, although distant from most of the blast furnaces which use them, reach their destination at relatively low transportation cost, by reason of the long water haul on the Great Lakes, the railroads carrying the ores from the various ranges to their ore docks at the shipping ports, five of which are located on the shores of Lake Superior, and two on Lake Michigan.

A full discussion of the cherty iron-bearing carbonates, the ferrous silicates and the pyrite quartz rocks cannot be given here. It is believed, however, that the iron-bearing formations were largely derived from the more ancient basic volcanic rocks of the Lake Superior region. "Where these igneous rocks were adjacent to the seas they would be leached by the underground water and the iron transported to the adjacent seas. It is probable that to some extent this leaching process also went on below the waters of the sea. The iron was probably transported to the water mainly as carbonate, but to some extent as sulphate. The carbonate would there be thrown down by oxidation and hydration as limonite, and the sulphate in part as basic ferric sulphate. Much of the sulphate was probably directly precipitated as sulphide by the organic material. The limonite would be mingled with the organic matter which was undoubtedly present, as shown by the associated carbonaceous and graphitic slates and shales. When deeply buried the organic matter would reduce the iron sesquioxide to iron protoxide. By the simultaneous decomposition of the organic matter carbon dioxide would be produced, which would unite with much of the protoxide of iron, producing the pyritic carbonates. Where the iron was brought to the sea mainly as sulphate the direct reduction of this salt by organic matter would form iron sulphide with little or no carbonate. Simultaneously with the production of these substances, chert was formed, probably through the influence of organisms. Some of this silica would unite with a part of the protoxide, producing ferrous silicate. More or less mechanical sediment would also be laid down. Thus the original rocks—the cherty iron carbonates, the ferrous silicate rocks and the pyritic cherts—would be produced.

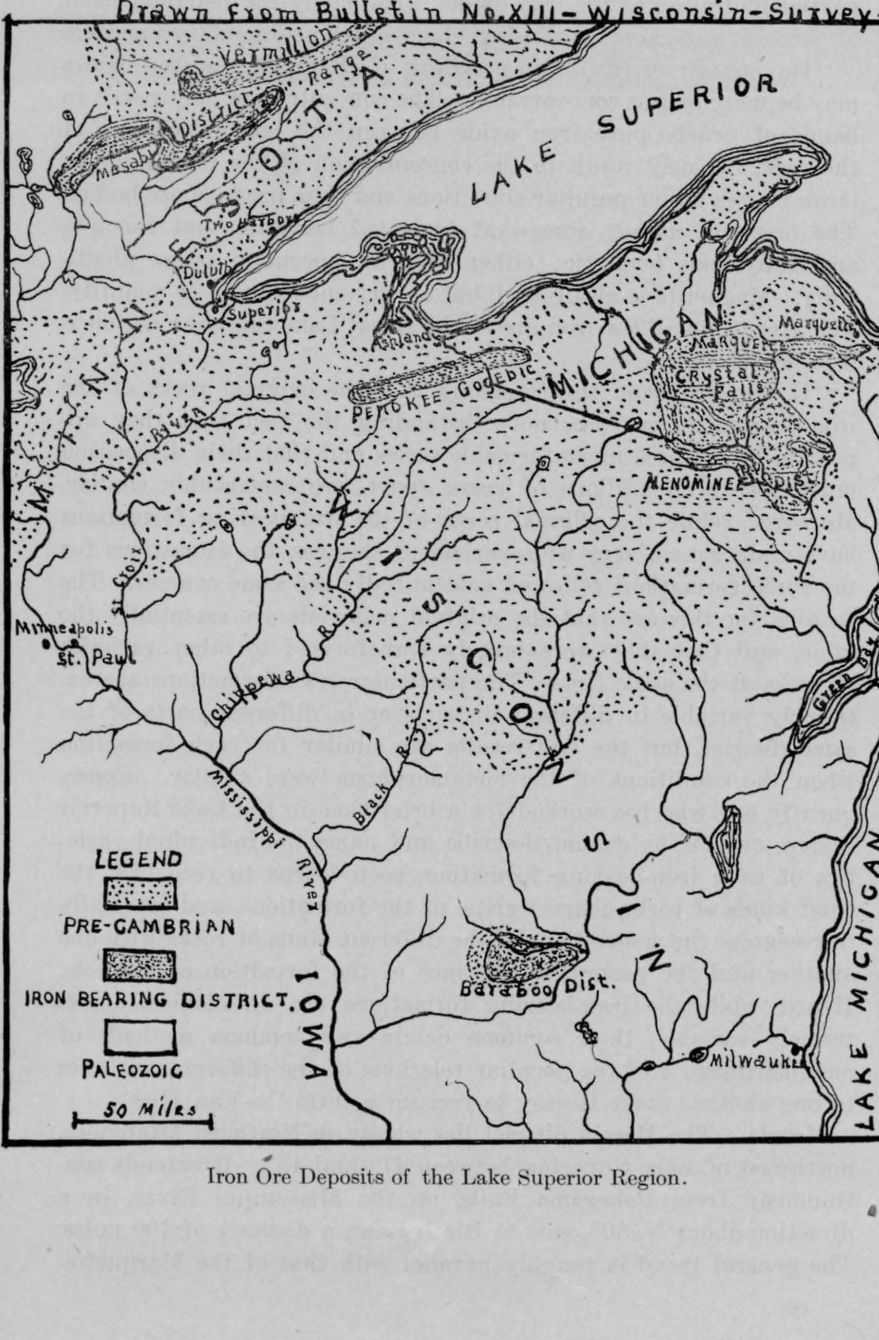
"It has chanced that at three different periods in the history of the Lake Superior region these processes of the development of the original rocks of the iron-bearing formations have occurred extensively. While this might at first be thought remarkable, there is no good reason for thus regarding it. At some time during each of the Archean, Lower Huronian, and the Upper Huronian periods the quiescent conditions of chemical and organic sedimentation have occurred, and since the iron-bearing volcanic rocks were each time available for the work of underground waters and sea-waters, naturally iron carbonate and the other original rocks have been produced. In each period the source of the material and the process of its formation were essentially the same.

"The alterations of the original rocks of the iron-bearing formation have been along two general lines, depending upon whether the iron-bearing carbonate or ferrous silicate or pyrite, when altered, was at the surface or at a considerable depth. Where the rocks were altered at or near the surface, so that oxygen-bearing waters were abundant, ferruginous slates, ferruginous cherts and ore bodies were produced. Where the iron-bearing carbonate was deeply buried when altered, and especially where altered in connection with igneous rocks so that the temperature was rather too high, the rocks which were produced were amphibolic and magnetic slates and schists. The formation of the ferruginous slates and ferruginous cherts from the iron-bearing carbonate is usually a process of liberation of carbon dioxide and of oxidation and hydration of the iron. Where oxidation takes place with little hydration, jaspilites may be formed. Where pyrite is also present the process is that of oxidation of both the sulphur and iron and partial hydration of the iron oxide. Ordinarily the rearrangement of the iron and chert emphasized the original sedimentary banding.

"During any of the above processes of alteration the iron oxides may be more or less concentrated. The concentration may result in bands of nearly pure iron oxide between the leaner portions of the rock. It may result in the concentration of the iron oxide in large masses under peculiar conditions and thus produce ore bodies. The ores are mainly somewhat hydrated hematite, but limonite and anhydrous hematite (either earth or specular) occur plentifully. Magnetite is also found, but is very subordinate in quantity. The great mass of the iron ore of the Great Lake Superior region is iron sesquioxide.

"It appears from the foregoing that the original rocks of the iron-bearing formations, notwithstanding the fact that they appear to be in three unconformable series and that their disposition must have been millions of years apart, are remarkably similar. Moreover, while the original rocks of the iron-bearing formations have undergone a very wide variety of changes, the alterations for the three formations followed substantially the same courses. The reasons for this are that the original materials are essentially the same, and that they were largely transformed to other varieties of rocks at the same time. The particular transformations are extremely variable in different districts or in different parts of the same district, but the end results are similar for each formation when the conditions of the metamorphism were similar. Consequently one who has worked for a brief time in the Lake Superior region, even if he cannot describe and name the individual varieties of each iron-bearing formation, soon learns to recognize the chief kinds of rocks characteristic of the formations, and especially to recognize the associations of the different kinds of rocks with one another and the general appearance of the formation as a whole. Hence, while the iron-bearing formations are lithologically extremely variable, their common origin and common methods of metamorphism and the peculiar relations of the different varieties to one another make it easy to recognize them."—Van Hise.

Mesabi.—The Mesabi district lies wholly in Northern Minnesota, northwest of Lake Superior, between 47° and 48°. It extends continuously from Pokegama Falls, on the Mississippi River, in a direction about N. 60°, east to Birch Lake, a distance of 100 miles. The general trend is roughly parallel with that of the Marquette-



Iron Ore Deposits of the Lake Superior Region.

Penokee-Gogebic and Vermillion district. West of the Mississippi the Mesabi formations undoubtedly continue, but they are so deeply buried with glacial deposits that they have not been traced.

The formations of the Mesabi series lie along the south slope of a ridge known as the Giant or Mesabi (Chippewa for Giant) Range. This ridge, while extending in the general direction named, has several gentle bends, and near the center of the district a relatively sharp bend known locally as "The Horn" carries the ridge and the iron-bearing formation about six miles to the south. The elevation of the range is seldom more than 400 feet above the level of the surrounding country. These higher elevations are found mainly in the central and eastern portion of the district, the elevations gradually decreasing to the west.

The Mesabi iron ores are for the most part soft, somewhat hydrated hematite, although soft limonite ores are present in subordinate quantities. Their texture varies from exceedingly fine-grained "flue dust" to a fairly coarse, hard and granular ore, breaking in parallelopiped blocks. In either case the ores need but little blasting to allow the steam shovel to take them from the bed. The fineness of many of the ores has prevented the use of large percentages of them in blast furnace charges. The iron content when dried, computed from cargo analysis, varies from 58.97 to 64.85 per cent., with an average of about 63.28 per cent. The phosphorus content varies from 0.025 to 0.080 per cent., with an average of about 0.042 per cent. The silica content varies from 2.50 to 9.20 per cent., with an average of about 3.38 per cent. The water content varies from 6.81 to 14.11 per cent. and averages about 10.78 per cent.

Few of the mines have reached the bottom of the deposit, but explorations show that in most of cases the ore extends to no great vertical depths. In many places the bottom of the rich part of the deposits are at a depth less than 200 feet, and but few deposits extend to a depth as great as 300 feet. It is clear that the Mesabi ore deposits are shallow as compared with those of some of the other iron-bearing districts of the Lake Superior region. This is due to the very gentle pitch of the deposits as compared with the steep pitches of the deposits in other districts. But the shallowness of the deposit is much more than compensated for by its great breadth and length. Minnesota contains more high grade ore than any other equivalent area in the Lake Superior region, and the Mesabi district as a whole has vastly more ore shown up than any other Lake Superior district.

The common method of mining in this district is to strip off the drift and load the ore directly from the deposit into the cars by the use of the steam shovel. The large open pits with trains running in and out and steam shovels loading from the banks to the train are characteristic sights in the district, but there are as many or more mines operated by underground work. The greatest stripping at Mesabi is the Shenango mine of the Oliver Company, where there is an average surface of about 108 feet.

For the season of 1906 the Mesabi Range made a total shipment of more than 23,600,000 tons of ore.

Origin of the Ore Deposits.—"They are mainly secondary concentrations in pitching troughs with impervious basements by downward moving waters, and subordinately oxidations in place. The process is the one outlined below. Iron from carbonate and silicate, taken into solution by the descending waters, was carried to the pitching troughs, and there met other waters bearing oxygen more directly from the surface, resulting in the precipitation of the ore. The solution of the silica was a simultaneous process and was favored by the large quantities of water concentrated in these troughs. The ores are very porous, and show decided indication of slump. This seems to be conclusive evidence that the silica has been dissolved more rapidly than the iron oxide was put in its place.

"The meteoric waters, entering the pervious iron-bearing formation at the higher northern ground, followed the troughs transverse to the range down the general slope, and mainly issued on the low ground before passing below the impervious slate. The higher geological horizons, the horizons near the overlying slates—were not in general transformed to ore deposits. When the ore deposits do approach the slate they are usually found to grow lean and thin. These were the places where the waters were ascending and issuing, and such waters were deficient in oxygen, and hence the circulations were not favorable for the development of large ore deposits of good quality.

"The waters were confined below the impervious strata, probably mainly slates, at different horizons, although principally in horizons some little distance above the bottom of the formation. In some cases, as shown above, the presence of slaty layers has not prevented the concentration of ores upon an impervious basement lower down, since between the outcrops of two sets of relatively impervious strata there is a broad area where meteoric waters may enter. However, in most cases there is a considerable thickness of apparently barren iron formation material below the iron ore deposits. In the Penokee-Gogebic district all the ore deposits, with the exception of the Iron Belt and the Atlantic, are at the bottom of the Ironwood formation and rest upon the Palms formation, and one might anticipate that the same condition of affairs would obtain in the Mesabi district, and that the ores would rest upon the Pokegama formation. The apparent absence of large ore deposits at the bottom horizon in the iron-bearing formations in the Mesabi district is probably explained in most cases by the fact that the part of the iron-bearing formation below the impervious layer, whether this layer be slate or impervious chert, was not sufficiently thick to furnish material out of which such ore bodies could develop. In some cases, however, it may be ascertained that the lower part of the formation was originally of a different and somewhat less favorable character than the rocks rich in iron carbonate and ferrous silicate out of which the ore deposits developed."—Van Hise in "Treatise on Metamorphism."

Penokee-Gogebic District.—This is a narrow belt south of Lake Superior. The eastern and most profitable third of the district is in Michigan; the western and less profitable two-thirds of the district are in Wisconsin. The important towns of this region are Hurley, Ironwood and Bessemer. The iron ores of the district are soft, red and somewhat hydrated hematite, with a very subordinate amount of hard steel-blue hematite. The iron content from cargo analysis varies from 53.45 to 65.42 per cent. and averages about 61.32 per cent. The phosphorus varies from .127 to .138 per cent.

"In the Gogebic district we have the concentration of the ores somewhat fully worked out. The descending waters on the higher elevations worked to the east or west along the dikes to the north-south intersecting drainage. During this journey the ores were collected and deposited. Below the valleys the waters were ascending and escaping. Of course in pre-glacial time, when the main part of the ore deposition was done, many of the drainage lines were much deeper than at the present, for the valleys are filled, in some cases, to the depth of many feet.

"There is no reason to suppose that the ore deposit of the Penokee-Gogebic district may not extend to as great a depth as in other districts of the Lake Superior region."—Van Hise.

Menominee District.—This district lies wholly in Michigan and extends from the Menominee River in a southeastern direction. The area that has been mapped is about 20 miles long and on the average of six miles wide. The Huronian belt has not been mapped farther east because it is capped by the Cambrian sandstone. It has not been mapped west of the river because of the overlying Pleistocene. The important towns of the district are Iron Mountain, Quinnesec, Norway, Vulcan and Waucedah.

The iron ores of the district are principally grey, finely banded hematite, and to a subordinate extent dense, flinty black hematite. The iron content from cargo analysis varies from 40.64 to 64.4 and averages about 56.6 per cent. The phosphorus varies from .009 to .738 per cent. and averages about .083 per cent. The silica varies from 2.07 to 39.10 per cent., with an average of about 7.57 per cent. The water averages about 7 per cent. The total production since 1877, when mining first began, to 1907, was more than 39,500,000 long tons. Recently good finds have been made and all exploration shows encouraging results, and large contracts with diamond drill companies have been made for the coming year.

It is not generally known that a tradition exists among the Menominee Indians (who were the only inhabitants of this range prior to the discovery of iron ore), that if any member of the tribe should disclose to a white man the existence of a mineral deposit his speedy death was sure to follow. This superstition may have been influential in the lateness of the mines' discovery and of their subsequent operations—on this range; for by bringing specimens (which could readily be obtained) to the trading posts they would have incited earlier investigation. Be that as it may, it is incomprehensible why the existence of ore deposits in such vast quantity should have remained unknown for so many years.

Another embarrassment, and one of more substantial import, was the impression that iron ores of quality and quantity could exist only in the Marquette range. The geological formations of other districts, where indications of ore were prevalent but not corresponding exactly with those of the Marquette district, seemed to preclude the possibility of the existence of paying ore. This impression was general and was so effective as to influence the most active and noted explorers. The edict had gone forth: "There was no good ore outside of the Marquette country," and, blinded with this phantasm, explorers strolled aimlessly over locations from which millions of dollars' worth of ore have since been extracted and millions more are yet to come.

These iron ranges have shown a striking example of rapid development. This is especially true of the lower Menominee range and the Iron River, Crystal Falls, Gogebic and Minnesota districts; ore has been disclosed over a territory, the value of which a short time previous, if it had any, was based solely upon the pine timber standing thereon.

The location of this district, remote from water and rail transportation, the reported severity of its climate, as also the reported bareness of its soil, all tended to divert immigrants. Sawlogs and sawmills were the only products shipped from the Menominee and its tributaries.

The first exploring party to enter the territory embracing the lower Menominee range, was headed by N. P. Hulst of Milwaukee. As a representative of the Milwaukee Iron Company he began exploring in the summer of 1872. The exploration was discontinued in the fall of that year. In the spring of 1873 exploration was again begun and carried on with success. In the spring and summer of 1874, 55 tons of iron ore was hauled to Menominee on sleds and wagons and smelted in the furnace at that point, with a mixture of hard ore from Jackson and Winthrop. The last furnace charge consisted entirely of the Menominee range ore, thus establishing its tractability. Robert Jackson, superintendent of the furnace, spoke in the highest terms of the quality of the ore. This was practically the first test of standard ore from the Menominee range, and it was the incentive to rapid and successful exploration along the entire formation.

The total product for the year 1906 was almost 3,000,000 tons, with a force of about 3,000 employes. The product is keeping up to, if not exceeding, former years, with the number of employes somewhat reduced, because of the application of improved machinery, underground haulage and improved methods of mining. The quality of the ore produced is not so good as in former years, yet all finds a ready market and no complaints are heard from the operating corporations. The scale of wages is as high, if not higher, than ever before on this range. This standard of pay, in the face of reduced value of ore, is maintained only by the use of improved machinery and by skillful management in the raising and shipping of the product.

It is estimated that the ore is now delivered on cars at some of the mines at a cost of 60 per cent. less than in former years. When ore was worth from $8 to $12 per ton the operator could afford to be somewhat indifferent as to the cost of production, but with a price of $4 at the end of the market, it behooves the management to exercise the utmost economy and skill in the operation of the mine.

Notwithstanding that the existence of ore in shipping quantity was fully demonstrated in 1874, and notwithstanding the heavy demand for lumbering supplies (which at that time were hauled on wagons from Menominee), it was not until 1877 that the Menominee River Railroad was completed in Quinnesec. In 1880 the road was extended to Iron Mountain and thence to Iron River, Crystal Falls and the Gogebic range. The delay in the construction of the road as far as Quinnesec arose from a matter of doubt on the part of capitalists as to whether this range would sustain a railroad costing $475,000. The road paid for its construction in its first year; and this little stretch of railroad from Iron Mountain to Escanaba since it began operations, has paid for many hundreds of miles of track on the western prairie. We have now three railroads penetrating the range: the Chicago & Northwestern; Chicago, Milwaukee & St. Paul, and the Wisconsin & Michigan. All are doing an ore-carrying business. This, with other traffic incidental to the operation of our mines and the development of a comparatively new country, provides ample business for both passenger and freight traffic.

Marquette District.—This is a comparatively small east-west belt. It lies wholly in the State of Michigan and gets its name from the city of Marquette. The more important towns are Marquette, Ishpeming, Negaunee, Champion and Republic.

The iron ores of the Marquette district are mainly soft, red hematite. Hard specular hematites are also important. Magnetite and limonite are subordinate. The iron content from cargo analysis averages about 63 per cent. The phosphorus averages about 0.083. The silica content varies from 1.30 to 38.27 per cent. and averages about 4.8 per cent. The water content varies from 9.45 to 15.29, with an average of about 5.49 per cent. The total production of the district from 1854, the first year of shipment, to 1906, inclusive, was about 77,500,000 long tons.

Nearly all writers on the geology of the Marquette and Menominee district have maintained the general equivalency of the iron-bearing series in the two districts. The opinion is based on the unconformability of the clastic series in each district above a series of gneisses and crystalline schist and upon the lithological similarity that exists between certain members in both series. The sequence of the two districts appears to be similar, but the rocks of the one region have not been traced into the other, so that it cannot be said that this similarity proves the formations in the two districts to have been found contemporaneously.

It has long been known that many rocks are possessed of decidedly magnetic properties, due to the presence of varying quantities of magnetic iron ore. By mining engineers and prospectors this has been turned to a practical use in aiding in the location of iron mines when the ore is of a magnetic kind. In the iron ranges of the south shore of Lake Superior the magnetite is rarely concentrated in large bodies and its known occurrence as such is restricted to a small part of the western Marquette district, where in one producing mine it now forms practically the whole product and in another a variable but usually important part of the whole. It is well understood that disturbances of the magnetic needle, however great, do not mean workable deposits of magnetite, but such disturbances may lead to the discoveries of rich ores other than magnetite.

Workable iron ores have been found at many places from east of Negaunee to Michigamme and Spurr, on the northwest, and to Republic on the southwest. In this respect the Marquette district differs from the Mesabi and Penokee districts, which have long stretches of iron-bearing formation, which, as yet, have not been fruitful. In general the portions of the ore deposits which reach the surface are located on the middle or upper parts of the slopes, although in some instances the ore deposits are entirely below low-lying areas, but in these cases the impervious basement material makes a surrounding amphitheater.

Vermillion Range District.—This iron-bearing district occupies a broad belt in Minnesota. The area extends from Vermillion Lake on the west to the international boundary on the east, in the vicinity of Gunflint Lake and Lake Saganaga. The belt is about eighty miles long and varies in width from 4 to 10 miles. The chief towns of the district are Tower, Soudan and Ely.

The iron ores of the Vermillion district are hard blue and red hematites. The ore is partly massive and partly brecciated. The iron content from cargo analysis varies from 60.47 to 67.37 per cent., with an average of about 63.7 per cent. The phosphorus varies from 0.040 to 0.131 per cent. and averages about 0.057 per cent. The silica varies from 2.55 to 7.67 per cent. and averages about 4.78 per cent. The water content averages about 5.50 per cent. The total production of the district since 1884, the first year of shipment, has been about 25,000,000 long tons.

"The large ore deposits of this district are located below crests or slopes. From the study which has been given this region, it may be concluded that the ore deposits of the Vermillion district were produced from original cherty iron carbonates. The iron-bearing carbonate was partly oxidized in situ, thus producing some of the iron oxide. Another and larger portion of the iron carbonate was contributed by descending waters, and iron oxide was precipitated in the troughs by oxygen-bearing solutions. The analogy between the ore deposits of the Vermillion district and the great ore deposits of the Marquette district is very close. The pitch of the ore deposits is parallel to the range, the same as in the Menominee, Marquette and Penokee-Gogebic districts." The shipments from the Vermillion range for 1906 were 1,800,000 tons.

Crystal Falls District.—This includes the Metropolitan, Commonwealth, Florence and Iron River areas. The greater part of the district is in Michigan and the remainder in Wisconsin. The chief towns are Crystal Falls, Florence, Commonwealth, Mansfield, Amasa and Iron River. This district was so named from the town of Crystal Falls, the county seat of Iron County. The iron-bearing area along Paint River, near the town of Crystal Falls, was first called in literature the Paint River district. As soon as the town was begun, about 1880, the name of the town was applied to the district. The area situated on the Upper Peninsula of Michigan serves as a connecting link between the two great iron ore producing districts: the Marquette and Menominee. The Crystal Falls district is of itself of considerable economic importance, as will be seen, though not deserving to be ranked with either of the two above-mentioned iron regions.

The total production of ore from 1882, the first year of shipment, to the present time, is about 14,500,000 tons. The ores are chiefly a soft red hematite, although in some places it is hydrated and graded as brown limonite. The iron content from the cargo analysis varies from 54 to 63 per cent., with an average of about 59 per cent. The phosphorus ranges from 0.049 to 0.7 per cent., with an average of about 0.40 per cent. The silica ranges from 4 to 9 per cent., with an average of 5.5 per cent. The water varies from 3 to 9 per cent., with an average of 7.5 per cent.

The Crystal Falls district is not sharply defined, but consists of a continuous belt of more than thirty miles in length, varying in width from two to five miles, lying wholly within the drainage basin of the Michigamme River and its principal upper tributary, the Fence River, and is continuous with the Marquette district on the northeast and the Menominee district on the southeast. It is, however, remarkable for the vast accumulation of volcanic rocks, which, while by no means absent from the adjoining district, do not there play so important a part.

"There volcanic rocks have associated with the rocks of sedimentary origin, as is shown by their well bedded condition and the rounding of the fragments. The Subaqueous rocks are, however, composed of little altered volcanic material, and evidently point to oscillation of the crust during the time of volcanic activity --such oscillation as has long been known as common in volcanic regions. Following the volcanoes and overruling them, probably unconformably comes a series of sedimentary rocks believed to belong to the upper Huronian. These comprise chlorite, ferruginous and carbonaceous slate, associated with quartzites, gray-wackes and small amounts of carbonate beds. It is this slate series that, with the exception of the Mansfield Mine, the ore deposits of the Crystal Falls district are found. Although a great deal of exploring has been done for iron ore in the Mansfield slates, only one large body of ore has thus been discovered, on which is the Mansfield Mine."

The iron ores at Commonwealth, Florence and vicinity were the first to be discovered in this district. At Iron River and vicinity ore has been taken from various mines for a number of years.

The Baraboo District.—This district has recently come into prominence on account of the discovery of iron ore. The district lies near the center of the southern half of Wisconsin. The length, east and west, is approximately 28 miles, and the width varies from two miles at the east end to 10 or 12 miles in the middle and at the west end. It covers an area of about 225 miles.

While the presence of iron in the Baraboo district was not definitely known until very recently, Prof. T. C. Chamberlain, in 1882, recognized the possibility of the occurrence of iron in the area of the quartzite ranges, as shown in the following statement: "In the Baraboo region of Sauk County large bunches of brilliant specular iron in veins of white quartz are often met with, but no indication of the existence of ore in quantity in the Huronian of this region has been observed. It is a matter of great interest that while we have in the Penokee and Menominee Huronian the same kinds and succession of rocks as in the iron district of Marquette, in the Baraboo country, and to the northeast from there we find a great development of the porphyry so characteristic of the Huronian iron district of Missouri. It is wholly within the possibilities that iron ores may yet be discovered in the Baraboo Huronian."

Iron ore was first discovered in the district in April, 1900. Exploration, however, began as early as 1887 by the Douglass Iron

Mining Company. The Baraboo iron ore is mainly red hematite, with a small amount of hydrated hematite. This district is adding largely to the production of the State.—(See Wisconsin Survey-Bulletin No. XIII.)

Canada.—In the Lake Superior region of Canada the iron-bearing rocks are known to have great development. In these rocks, at various places, are extensive belts of iron-bearing formations. These iron-bearing series are a direct extension of the series which have been productive on the United States side up to the present time; however, comparatively little exploration has been made and only a few mines opened in the ore region of Canada. The Michipicoten District is at present the chief ore producer. Sufficient development has not been made to insure that this district will be a great producer in the future.

The iron-bearing formation and the associated rocks have not been separately mapped, but when this is done it will undoubtedly be very helpful to the development of the merchantable iron ore districts of the Canadian region.

"While it may be possible that on account of glacial erosion the product of high grade ore in Canada may be less than in the districts of similar size and geological position on the United States side of the boundary, it cannot be doubted that in the future important quantities of ore will be explored in the Canadian Lake Superior region. Doubtless also this exploration would have been begun many years ago were it not for the duty which ores mined in Canada must pay when entering the United States."—Van Hise, 21st An. Rept., U. S. G. S.

Outlook for 1907 in the Lake Superior Ores.—A large amount of development has been done recently in the Lake Superior region and enormous amounts of iron ore lie exposed ready for the steam shovel. New companies are entering the ore field with vigor and are making explorations with a view of developing new ore lands. A sale of Mesabi lands just closed with the Buffalo & Susquehanna interests shows how anxious consumers are for iron. It is of a tract just north of the old Mesabi chief mine and consists of the lean and mixed character of that deposit. It contains, so far as now exposed, about 2,500,000 tons of ore, mostly of an ore that must be washed to become merchantable and carries on an average too much phosphorus to permit its use in the Bessemer process. It is a State lease, and in addition to the State 25-cent royalty, there is a second 25 cents a ton with a minimum of 100,000 tons, and a cash bonus of $70,000 for the lease. This bonus is equal to

3 cents per ton cash on all ore so far discovered, including ore that runs far too low to be available in its present form.

The advance in the base price of Lake Superior ores has been from 50 to 75 cents per ton, but the real advance has been greater owing to the lowering of the guaranteed iron content. The following are the base guarantees for 1907, as compared with the past season:

	Old Ranges.		Mesabi	
Bessemer Ores.	*1906.*	*1907.*	*1906.*	*1907.*
Iron per cent., natural......	56.70	55.00	56.70	55.00
Moisture	10.00	10.00	10.00	10.00
Iron per cent., 212°.........	63.00	61.12	63.00	61.12
Phosphorus...................	0.045	0.045	0.045	0.045
Base price	$4.25	$5.00	$4.00	$4.75
Non-Besse ers.				
Iron per cent., natural......	52 80	51.50	52.80	51.50
Moisture	12.00	12.00	12.00	12.00
Iron per cent., 212°........	60 00	58.52	60.00	12.00
Base price	$3.70	$4.20	$3.50	$4.00

Bessemer ore here is understood as ore carrying 55.60 per cent. iron and not over 0.045 per cent. phosphorus. Under these conditions the actual increase in price to furnacemen is 90 to 95 cents per ton for Bessemer ores, and 60 to 65 cents for non-Bessemers.

In considering the possibility of a material increase in ore tonnage from the Lake Superior region for the year 1907 several facts must be kept in mind. In the first place there will be no increase except from Mesabi. Old ranges are being worked to limit now, and of the class of ores, if a gain might be made, but little will be used. On the Mesabi are three railroads: The Duluth & Iron Range is at its limit at 8,000,000 to 9,000,000 tons for the season. The Duluth, Mesabi & Northern, which moved 11,000,000 tons in 1906 is prepared to forward 13,000,000 tons for 1907. The Great Northern, with over 6,000,000 in 1906, may reach 8,000,000 tons for 1907. The shipments of iron ore from the Mesabi and Vermillion ranges as given for the three railroads for 1905 and 1906 were as follows: For 1905, 21,711,409 long tons; in 1906, 25,484,546 long tons, an increase of 3,773,137 tons. These roads for 1907 can possibly put out an increase of 3,500,000 to 4,000,000 tons over 1906. As to vessel capacity there is no question. But new mining may be limited by the capacity of steam shovel shops and by the labor market.

The fear of an ore shortage existing in mid-summer created an early demand for iron ore for 1907 delivery, and consumers began to besiege shippers to make sales. These were held off until early in November, when almost the entire output for 1907 delivery was disposed of in a single week. The amount sold each customer depended upon his needs in previous years, and his standing as a customer had a good deal to do with the allotment. It was found even that the supply of iron ore that could be insured would not go around and some sales were subsequently made at a premium, despite the fact that the regular advance has been to the highest level since the Mesabi range was discovered.

In previous years difficulty with labor unions, combinations of vessel owners to affect the rates of transportation, the urgent demand for coal shipping and the heavy movement of grain has seriously affected the amount of tonnage in the ore trade. But it has never before been that the dangers of a shortage of iron ore has arisen almost entirely from the inability of the Lake Superior region to produce the amounts of ore the consumers have demanded. This has arisen from two sources. One of them is the fact that more furnaces have been placed in operation, demanding supplies from the Lake Superior region; most of the furnaces have been active more continuously than ever in their history, and the sales of Lake Superior ore have been scattered over a wider area. The other condition which is most striking is that the high grade ores are rapidly becoming more scarce, while the guaranteed iron content is less than it has ever been, demanding that the ore shippers must increase their output to produce the same amount of iron. With the production of pig iron constantly showing great advance it is not surprising that the Lake Superior region should have difficulty in meeting the needs of consumers. The car shortage did not hinder the ore shippers for the reason that the railroads, seeing they were so dependent for new equipment on the continued activity of the steel trade, set everything else aside and moved the ore as rapidly as it came down the lakes.

Although no material increase from the entire region will likely be made for 1907, it is expected from the Minnesota districts alone to send out 29,000,000 tons of ore, and all other areas where developments have been made will be worked to the limit.

Iron Mountain.

This is the name of a famous deposit of iron ore in St. Francois County, Missouri, forty miles southwest of St. Genevieve, on the Mississippi, and connected with St. Louis by railroad. The deposit is of rich and pure ore. It is magnetic and in some places acts strongly on the needle. The main body of ore was several feet in thickness and an immense amount of ore has been taken from this region, but the deposit did not prove as great as was expected from early investigation. A great deal of this ore was used in some of the Indiana furnaces.

At a recent meeting in St. Louis the stockholders of the Iron Mountain Company voted to dissolve the corporation for the reason that it "has not been actively engaged in business operation for a long time past, and has no indebtedness; and the aggregate value of the assets has been reduced by depreciation in the value of its real estate, to a small percentage of its capital stock of $3,600,000." The court has since granted the petition to dissolve and a committee has been appointed to wind up the company's affairs.

The Iron Mountain Company organized about forty years ago. The iron ore deposits of Iron Mountain and Pilot Knob, eighty miles southwest of St. Louis, were the basis. They were believed to be sufficient to make St. Louis the rival of Pittsburg and to supply the iron industry of the United States for an indefinite time. They were sufficient to secure the building of the St. Louis and Iron Mountain Railroad, which has since become part of the chief line from St. Louis to the southwest; the construction of a blast furnace at Carondelet, a suburb of St. Louis, and the establishment of large iron works.

The Iron Mountain, however, proved to be only a surface deposit which was gradually worked out. Exploration failed to show anything of value in depth, and finally the mine was abandoned. The mining town of Iron Mountain dwindled down to a small village. For years the output of the ore was insignificant, and for some ten years past it has been nothing.

The company was honestly managed and the stockholders received a very large per cent. on the par value of their shares in dividends.

The Iron Mountain tract of 12,000 acres is to be sold and the greater part of it except the part occupied by two granite quarries is to be turned into a stock farm.

BIRMINGHAM.

The iron mines of the Birmingham district are prominent in the industry of the United States. Mining is changing from its period of open cut to underground working, and although the cost of production may have slightly increased, it has not been materially affected, as the yield has been enlarged by improved methods and machinery and substantial growth is assured.

The ore occurs in the Clinton formation of the Red Mountain, a range of hills. Two ridges extend south-east, north-west, and border a valley, the eroded crest of an anticline. On the valley sides of these flanking ridges are found the beds which have been explored by the erosions that removed the crest. Mining is confined largely to the eastern outcrop, which is worked extensively for 150 miles. Near Birmingham the outcrop has been stripped and work carried on underground for 15 miles.

The ore deposits are uniform as viewed along the outcrop, but as the workings are shallow, seldom exceeding 1.000 to 1.800 feet, change in regularity cannot be determined. The strata range in thickness from 2 to 20 feet, often aggregating 35 feet. Shale partings break up the continuity of the beds, for example a 20-foot strata may in the course of a mile, divide into two or more distinct parts, on account of the shale partings, varying in thickness from the fraction of an inch to a foot or more.

There are two kinds of ore in the district, aside from that of the Siluro-cambrian beds occupying the center of the Red Mountain. These ores, though hard and soft hematites, are intimately associated with each other in the same stratum and were formerly of the same composition. The leaching of the surface water is responsible for the change in lime content. The percentage of iron in the two ores is close to 37 and 48 per cent., while that of lime is 1.6 and 1.5, respectively. They may be designated as high and low silica, or self and non-fluxing ores, the variation of lime is more marked than that of silica. The hard ore is used more than the soft and has an average composition of:

	Per cent.
SiO_2	13.4
Fe	37.4
CaO	16.2
Al_2O_3	3.18
P	0.37
S—	0.07
CO_2	12.24
H_2O	0.5

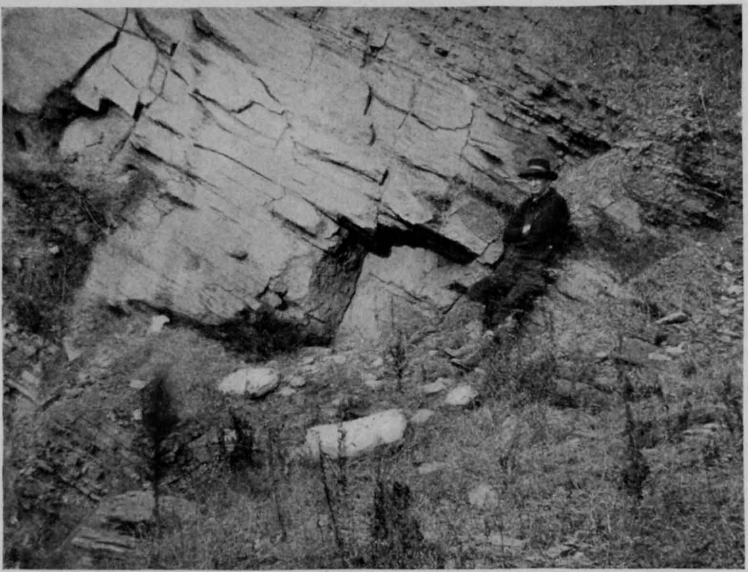
In many mines the lower limit of soft ores has been passed. Beside the "hard" and "soft" ores, there is another known as fossil ore which has the same characteristics as the non-fossiliferous and may be hard or soft according to leaching action. This is composed of fossils, usually quite small, which give a granular appearance. All ores of the Clinton formations are distinctly red.

Dip-Slope Mines in Suburb of Birmingham, Alabama.

Mine and Tipple at Readers, near Birmingham, Alabama.

The Potter mines, with an area of 1,800 acres, fourteen miles south of Birmingham, in Jefferson County, are considered among the most desirable in the Red Mountain district. These ores carry sufficient lime to be practically self-fluxing and are lower in silica than those nearer Birmingham. They run about 31 per cent. in iron and from 14 to 16 per cent. lime.

Plate XVII.



Iron-Ore Layer at Readers, near Birmingham, Ala. Nine Feet of Fossil Iron Ore.

Production.—In the Southern territory, and in Alabama in particular, work was greatly curtailed during the last part of 1906. Several furnaces were shut down for repairs and others were able to work only about half-time because of scarcity of raw material supplies caused by the railroad car shortage being so intense, consequently most of the Alabama iron companies were behind more or less in their deliveries, but sales for 1907 were made right along and all iron wished before April was termed practically "spot" iron. Spot iron is quoted at $23 per ton, No. 2 foundry and soft. The markets in Chicago were somewhat delayed on account of an advance in Southern pig iron freight rates—Birmingham to Chicago and adjoining points—from $3.90 to $4.85, effective February 1, 1907. On quick delivery No. 2 iron brings $21@23, Birmingham, or \$24.65@26.65, Chicago, the range being wide on account of diversity of millers' needs and the scarcity of the supply.

Much of the Alabama iron is used for the manufacture of sugar-making machinery for the Southern States and also Cuba and Mexico. In the Birmingham district the ore is mostly smelted in furnaces only a few miles from the mines. Special railroad cars haul the ore to the furnaces. These cars carry 30 to 50 tons each. During the past summer there was great activity in mine development and in new equipment, which will in the future give a much increased production of ore at reduced cost.

INDIANA.

Indiana is pre-eminently an agricultural State, but in recent years it has rapidly passed into the front ranks as a manufacturing State. Many of the largest and most modern factories and mills have been founded within its boundaries and other great manufacturing concerns have works under way of construction. The finding of natural gas and oil, the abundance of coal, the inexhaustible supply of limestone, good cement shales, excellent fireclays, together with the splendid transportation facilities, have all added to the building up of great enterprises, which have brought into the State millions of dollars to be invested in economic interests that are paying handsome dividends on the money spent.

The supply of raw materials within the State is unlimited; new developments are being made along many lines and old interests are being revived, which were formerly held in check through lack of means of transportation and inexperienced management.

To say that Indiana was at one time a chief iron-producing State might appear to be misleading, but when we go back to the years of 1830-1870 and find a dozen blast furnaces in operation and producing a fairly good tonnage of iron, we cannot fail to see that Indiana was a large producer of iron. Some of the furnaces used exclusively Indiana ores, others worked these ores mixed with foreign ores, others used only such iron ores as were shipped to them from deposits like "Iron Mountain," Missouri. The furnaces were located as follows: St. Joseph Iron Works, at Mishawaka, at the extreme northern edge of the State; one at Logansport; the "Old Virginia," or "Cincinnati," Furnace, in western Monroe County; the Richland Furnace, in Greene County; the Irontown Furnace, in Martin County; the Brazil, the Lafayette, or Masten, on Otter Creek, south of Brazil; the Planet or Star, northeast of

Harmony, and the two Western Iron Company furnaces at Knightsville, make up the list for Clay County; the Indiana Blast Furnace on Brouillett's Creek, near Clinton, in Vermillion County, and the Vigo Blast Furnace at Terre Haute, the last one to go out of blast. All of these furnaces have long since ceased operation and only little remains to mark the location of the big iron industries of the State which went into decline, yet leaving a more or less interesting history.

Eastern furnaces with lower railroad rates and better facilities for handling ore, and the opening of the great ore deposits of the Superior region and other districts has kept Indiana from returning to the manufacture of iron. But in the last few years interest has again revived in the ore deposits of the State, and the construction at Gary, Indiana, of what will eventually be the largest system of blast furnaces and iron mills in the United States makes it an assured fact that Indiana is again to become one of the chief iron-producing States of the Union, although most of the raw material may come from the Lake Superior region, but nevertheless the iron ore deposits of Indiana are well worthy of consideration and will undoubtedly prove a paying investment to those who carry out their development.

There are in the State several varieties of iron ore which may be classified as follows:

1. The Geological Formations.—The limestone, sandstone and shales, which contain from one to fifteen per cent. of iron and are of value in this connection only in that they may be shown to be the source of certain ore deposits.

2. Hematite.—The true hematites are comparatively rare. The red ochre variety is somewhat common, but usually quite impure from clay. The most abundant variety is a clay ironstone, a compact reddish material and highly siliceous. This class, however, more truly belongs with the limonite or brown hematite variety. Radiated and kidney-shaped masses are also found which approach the true red hematite variety very closely. Formerly the true hematites probably formed a much greater part of Indiana deposits, but it has been changed by the action of atmosphere, water, organic matter, etc., into limonite and siderite.

3. Limonite.—(a) Brown clay ironstone variety found in compact banded layers and nodular masses impure from clay. By drilling and other investigation it is found that these limonites are derived from carbonates which have been highly oxidized. (b) Bog ore of recent formation, loosely aggregated ore from marshy

ground, deposited chiefly from the surrounding soils; it is often found intermixed with and replacing twigs, etc. This variety may be found in a greater or less degree in almost any part of the State.

One usual result of the decomposition of any iron-bearing mineral is limonite. The decomposition by water, carbon dioxide and organic acids produces soluble iron salts, which are carried to some valley by the streams, and by oxidation the relatively insoluble limonite forms as a scum on the water and then sinks to the bottom as bog ore. In time, by pressure, heat, etc., these deposits are compacted. Notable examples of this decomposition and deposition are to be found in many of the streams of Martin County (see Report on Martin County).

4. Carbonates.—We have stated that limonite may be formed by the high oxidation of carbonates and it is also true that limonite, by the action of decaying vegetation, may be changed to carbonate. Thus iron ore is accumulated. In the presence of excess of organic matter it retains the form of ferrous carbonate. In the coal measures iron carbonate is largely found as a stony material, impure from sand, clay, etc., and may be massive, concretionary, banded or in the form of clay ironstone. When found massive, there is also frequently found associated with it more or less bituminous and earthy matter to which the term "black band" is applied; this bituminous matter may be somewhat equally diffused through masses of ore, giving it an almost black appearance. The concretionary form is very common and is composed of fairly compacted centers of carbonate ore, coated with thin layers of brown iron oxide.

5. Kidney Ore.—This includes all the ores in concretionary form and the name is derived from the peculiar kidney shapes of the concretions. In strata where two or more substances are found, it appears that there is an attraction of like for like, and the more soluble particles diffused through the more fixed segregate themselves into nodular masses. The concretion begins to grow about some nucleus, often some shell or other organism. In connection with sandstone the iron concretions are oxide of iron; in clay strata they are of carbonate, usually with a thin coating of oxide. These nodules are sometimes solid and others are hollow. They vary in size from that of a pea to more than a ton in weight.

6. Limestone Ore.—These are the ores which occur upon, or very near, the top of a limestone stratum and are regarded as replacements of limestone by ferruginous solutions, derived from overlying sediments. These ores are in some cases found occupying

a broader field than the limestone, but if they occur near the stratigraphic position of the limestone the term is still applied. The presence of limestone has an important influence on the precipitation of ferrous carbonate, and where both iron and calcium carbonates are present the former has in many cases replaced the latter. The iron content of the overlying formations has been carried down and deposited upon the limestone, which is afterward dissolved and carried away. The limestone ores carry a small percentage of lime.

7. Magnetite.—Magnetic ore is found in Indiana only in some of the black sands and in very small amounts. By dragging a magnet through these sands the particles of ore are gathered up.

8. Sandstone Ore.—This is a highly siliceous ore and is somewhat abundant. It is formed in part by replacement of the sandstone, but chiefly as a filling in the porous sandstone. It is richest on the outcrops, showing the downward and lateral movement of the iron waters.

While none of the Indiana deposits would be considered extensive as compared with the great ore-producing districts, yet the deposits aggregate a fair tonnage. The larger deposits which can be more easily worked would probably yield 15,000,000 tons of ore, and the smaller inaccessible deposits which would be easily worked out by the owners or the inhabitants if furnaces were in a reasonable distance, would bring the total up to at least 25,000,000 tons. In many cases the smaller deposits contain the best grade of iron; this would fully compensate for the extra cost in mining. Further developments and information from the use of the core drill may materially increase the above estimate.

The Methods of Prospecting in Indiana Fields.—The determination of the practical value of a mineral area in advance of actual mining is a matter of the greatest importance. Since large amounts of capital must be expended in the purchase of lands, building of railroads, installation of mechanical equipment, driving workings, etc., before a mineral property can be put on a working or paying basis, it is apparent that a great deal of prospecting by the most efficient means should prepare the way for actual developments.

The methods of prospecting in the Indiana fields as here described have not only been carried out in the iron ore fields of Greene and Martin counties, but also extensively in the coal fields of Southern Indiana and in the limestone and cement shale areas.

As a preliminary step in the development of the ore lands of Greene and Martin counties, the land was carefuly gone over and the ore outcrops and surface indications fully mapped. Then by the use of picks, shovels, drills and other hand tools and dynamite, vertical faces were cut on the outcrops extending from the surface down through the entire body of ore into the underlying formations. The length of these faces varied from five to 100 feet. In some cases where formations were broken and irregular some drift mining was done in order to determine more fully the dip and extent of the deposit. In some places in Martin County hundreds of tons of ore were removed from the face of the outcrop so that the information desired might be obtained. At points where surface indications seemed favorable and also back on the hill slopes some distance from the outcrop, where the hills do not rise to a great height above the deposits, shafts or pits from 6 to 10 feet in diameter were driven down to the line of the deposits or to greater depth, as were required to determine extent and thickness.

The cost of working a mineral area is determined to a large extent by the character of the formation and is affected by every variation in the pitch of the seam and the condition of the strata immediately overlying and underlying the mineral.

The methods described above are, however, of value only when ore outcrops are to be found or where the overlying formations are comparatively of little thickness. But when the deposits are far beneath the surface or when the hills rise to much elevation above the outcrops or line of deposits, the most economic and satisfactory prospecting is by drilling, as the cost of putting down a single shaft would be more than that required for many feet of drill holes.

There are thus five methods of prospecting to be considered. Each of these has certain advantages over the other, according to conditions. But for the average area the order of value would be as follows:

1. Mapping and Surface Outcrop Work, as Described Above.—The accurate delimitation of the iron-bearing or coal-bearing formations or any other formation containing valuable mineral product is of inestimable value to investigators. In many fields innumerable shafts and bores have been made at great distances outside of the possible mineral formations, thus wasting large sums of money. Although the result from mapping and preliminary work cannot be relied upon to definitely point out the places where the prospector will find iron deposits, they have enabled in a broad way to delimit the various formations and warrant the statement that iron deposits may occur in certain areas and that prospectors will not find iron deposit in certain others. This method proved to

be an excellent plan in the Indiana fields and could hardly have been dispensed with.

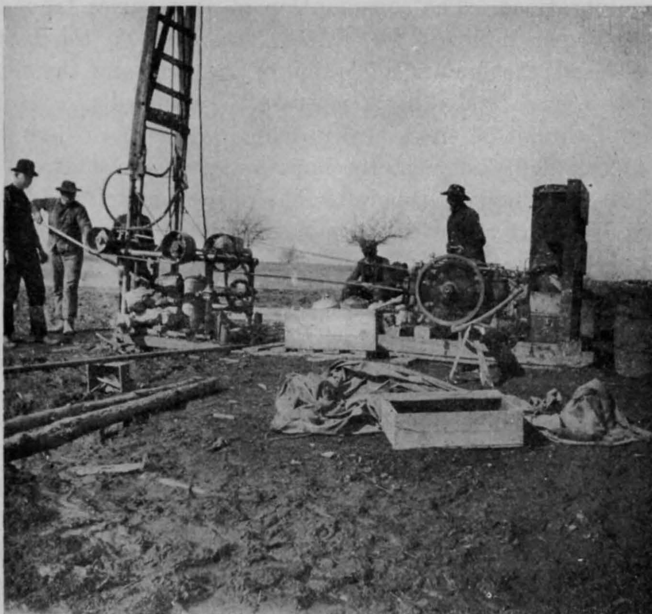
2. Sinking of Shafts and Pits or Drifting on the Deposits.—This method is necessarily slow and of great cost and has not been used in the ore field prospecting except as mentioned above.

3. Drilling With the Churn Drill.—This method is cheap and rapid and the samples from holes thus drilled consist of chopped-up particles representing the content of the hole, the various strata of which are necessarily more or less intermingled, so that the condition of the mineral as to purity and the character of the overlying and underlying strata are mere guess work. This method was little used in ore prospecting, but several holes have been put down with the churn drill within the bounds of the ore field in prospecting for oil and gas and the records made of formations through which the drill passed have been of assistance in working out the geology and practical value of the ore deposit.

4. Core Drilling With Chilled Shot or Saw-Toothed Bits.—This is an improvement over the latter method, but leaves much to be desired in the matter of drilling speed and condition of the core. There are no devices by which the cores are extracted carefully, nor is there the required pressure and smoothness to prevent the core from being broken up by vibration. Recently, however, a drill has been placed upon the markets in which a double tube core barrel is used. The bit is a cylindrical shell of selected steel, with a series of chisel edges, melted or forged in one end. The other end is threaded for attaching the core barrel. In operation the cutter and barrel are rotated and at the same time forced downwards. This cutter will rapidly and economically cut the majority of rocks. But there are some rocks so hard that the cutter will not bore them at an economical rate. In such cases the "chilled shot" method is used. Chilled shot, which is simply molten iron or steel "atomized," and suddenly cooled, will scratch glass. In drilling, the chilled shot is between the bit and rock and under the rotation and pressure of the drill rods the rock surface is milled or crushed away.

The chilled shot drills did not give satisfactory results in the ore fields chiefly because of lack of sufficient power (gasoline engines being used) and the soft and broken formation of the district. For drilling in solid strata as in the limestone fields of southern Indiana the chilled shot drill works at a good rate and gives a very satisfactory core. But in soft shales, coal and soft iron ores, the shot are lost in the material, the cores are worn and broken by the

Plate XVIII.



Chilled Shot Core Drilling in the Martin County Ore Field.

Rear View of Chilled Shot Core Drilling Outfit.

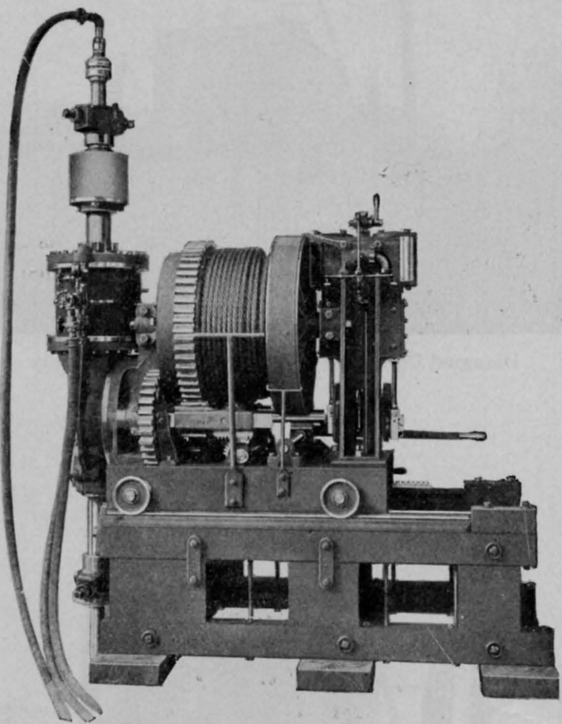
churning vibrations. The consumption of shot varies from ten to fifty pounds per hundred feet bored, according to the material. The slow speed, the jar and vibration of the drill and the slushing of the water in soft shales often cause "stuck drills." Holes of great depth cannot be successfully drilled with the ordinary style of chilled shot drill, but with the improved drill depths from 1,500 feet to 3,100 feet have been bored. The prices for drilling with the improved drill vary according to geological conditions from 30 cents to $2.00 per foot.

5. Drilling With the Diamond Core Drill; Using the Double-Tube Core Barrel.—Among progressive mining men the diamond core drill has replaced the methods of sinking shafts and drifting and the equipment of a modern mining concern is not considered complete without one or more diamond drills. Drills have been sent to the most out-of-the-way corners of the world, where they have acted as advance agents for the opening up of important mineral districts. In the South African gold field these drills have proved to be of inestimable value in verifying the persistence of mineral veins at great depths. Numerous holes have been successfully bored to a depth of a mile or over, including one near Johannesburg, recently completed at a depth of 6,340 feet from the surface.

The diamond drill consists of a line of hollow rods screwed together in five or ten-foot sections, rotated by an engine through a shaft and gearing and fed downward by hydraulic pressure regulated by finely graduated values. At the lower end of the rods is placed a double tube or "core-barrel," at the end of which is placed a bit, in which pieces of "black diamond," or carbon, are set, and which, as the rods are rotated under pressure, cuts a circular hole in the rocks, leaving a centerpiece of core undisturbed. At intervals, usually after drilling ten feet, the rods are withdrawn by means of hoisting mechanism, consisting of a derrick, or tripod, carrying a sheave wheel and a rope which is wound upon the drum forming a part of the drilling machine. The rods bring with them the core, which is caught and held by self-locking "core lifter." The core is then removed, the rods again lowered and the process repeated until the mineral body sought is found, or the desired depth reached.

Usually the cores are two inches in diameter, a dimension fixed upon after extensive experience. The cores extracted, even in friable formations, are practically complete, showing only a minute loss from abrasion and are a perfect index of the formations existing at the point drilled. The cores are placed in boxes made to carry from one to four sections and from three to ten feet in length, thus forming a permanent record. Vertical sections of the ore may be taken for analysis as required, the remaining portions being preserved.

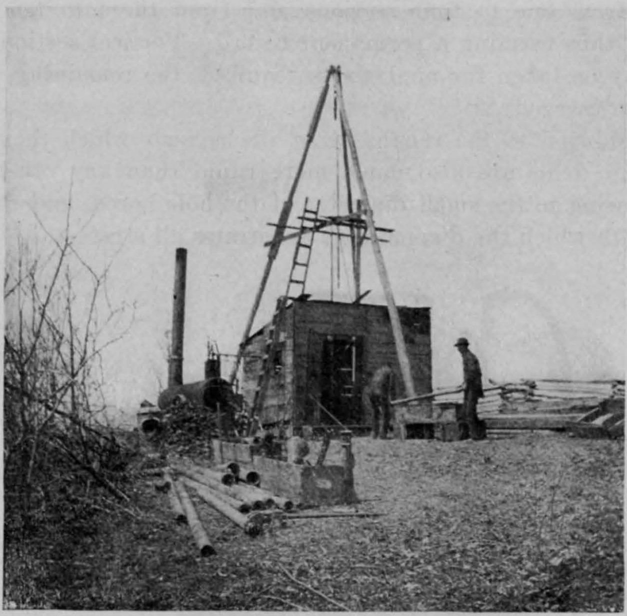
In addition to the reliability of the records which they secure, diamond drills are also much more rapid than any other coring drill, owing to the small diameter of the hole bored, and the readiness with which the diamond bit penetrates all strata.



Diamond Core Drill.

Several thousand feet of drilling have been done with the diamond drill in the areas of Greene and Martin Counties, and extensive use has been made of these drills in the coal fields of Warrick, Pike and Gibson Counties. In Martin County a two-inch core was removed at a cost of about $2.50 per foot. In Greene County the core was 15-16 inch in diameter and the cost per foot to the company would be somewhat less, as the company owned the drilling outfit and put down many holes. In the latter county

Plate XIX.



Diamond Core Drill in Operation, Martin County.

Removing the Mineral Core from Double Tube Core Barrel.

a few holes were drilled at an angle to determine the thickness of dipping formations. In fact, the diamond drill may be set to penetrate the strata in any direction desired, while the "chilled shot process" and similar methods are useless except on perpendicular holes. In Martin County considerable trouble was experienced in keeping a supply of water on account of the scarcity of water and the crevices in the sandstone through which drilling was done. The water is forced through the rods to keep the diamonds cool and to wash away the cuttings from the bit. Thus, in holes where the crevices and broken formations occurred, it was necessary to ream the hole and case it. Nevertheless the average number of feet drilled per day was fair and the greatest depth drilled in one day was a little more than forty feet. The average per day would be somewhat low on account of shallow borings and frequent moves.

The cost of diamond drilling varies within wide limits, depending upon local conditions as to labor, fuel, water, superintendence, availability of supplies, living expenses, etc. The "Engineering and Mining Journal" has the following to say on the subject of costs:

"A recent compliation of statistics with reference to the cost of diamond drilling, goes to show how variable is the cost of such work and how utterly impossible it is to fix anything more than general rules from which an approximate figure of cost can be deduced. Out of 20 holes drilled through jasper, marble and iron slate, and varying in depth from 110 to 1,100 feet, the average cost was \$3.14 per foot. Of this cost 39 per cent. went for labor, 22 per cent. for carbon and the remainder for fuel, repairs, supplies, etc. Another series of 16 holes, varying in depth from 94 to 380 feet, with an average of 314 feet, showed an average cost of \$2.70 per foot. Of this amount 38 per cent. went for labor and 13 per cent. for carbons. The cost of drilling in soft schist rock was as low as \$1.00 per foot, of which labor formed 66 per cent. and diamonds 30 per cent. The cost of drilling in hard syenite rock was twice that of drilling in tough diorite; the cost of the diamonds in drilling the syenite rock approximated 63 per cent. and the labor 38 per cent.; the carbon cost 30 per cent. and the labor 66 per cent. of the total. The speed of drilling varied from 6 to 25 feet per day, and the holes had a mean diameter of 1¾ inches."

The method of core-drilling indicates to the prospector the exact depth of the ore body from the surface and the thickness and character of the vein when found, as well as the nature of the material penetrated before reaching the vein. It is thus possible to estimate very closely the cost of the work of development, while the core of the mineral gives accurate samples for analysis. Of about equal importance, if the ore body is absent the drill indicates the fact, thus saving the cost of an exploratory shaft. Since the core may be preserved in boxes, each piece in its proper position, we have a record that is one of the best arguments that may be used to induce capitalists to invest in mineral properties.

The Kankakee and Lake Region.

This region is comprised of the counties of Lake, Porter, Laporte, St. Joseph, Elkhart, Lagrange, Steuben, Dekalb, Noble, Kosciusko, Marshall, Starke, Whitley, Northern Wabash, Fulton, Pulaski and the northern part of Newton and Jasper. This area includes more than 250 lakes, varying in size from less than a fourth of a square mile in area to a little over five and one-half square miles, and varying in depth from a few feet to 125 feet. The rivers and streams wind through marshes, with a slight current and without definite banks. The Kankakee marshes comprise the most extensive body of swamp land in Indiana. The original area of this marsh land in the seven counties drained by this stream was almost a half-million acres. The Calumet River is also noted for its low banks and the sluggish action of the water. Much has been done by the use of artificial ditches to drain these marsh lands, yet there are thousands of acres that for four or five months of the year are covered with from one to five feet of water and during the remainder of the year this area is little better than an immense bog.

In the margin of many of the lakes and in the marshes are found considerable quantities of limonite or bog iron ore, and peat formed by the partial decomposition of vegetation beneath the surface of the water. Although this ore is apparently abundant in many places and would yield a superior iron, yet the expense of removing the overlying material increases the cost of the ore so that it cannot be furnished in competition at present with the rich ores of the Lake Superior region. An excellent fuel, where great heat is required, has been produced by mixing about equal proportions of coal and peat, and when some such plan has been devised for converting the peat with which the ore is associated into a fuel that can be successfully used in iron manufacture, each may add to the value of the other and bring these marshes into more favorable notice.

Origin and Deposition.—The bog ore is usually found at the bottom of the peat bogs, often as a "hardpan" of iron ore, sometimes one or two feet thick. It is also found in masses scattered through the lower materials of the marshes; masses of several tons weight have been found in a few places. It is never crystallized, but grades from the loose, porous bog ore and earthy ochre of brown to yellow color to more compact varieties. Bog ore, or limonite, is a variety of brown hematite, usually quite impure from sand, clay, phosphorus, etc. It is often found intermixed with or replacing leaves or twigs. It collects in low places even where there is no decided bog. The manner in which this iron ore accumulates is very interesting and in a geological point of view very important.

A sedimentary deposit of bog iron is finally concentrated by precipitation of the mineral in a marsh or lagoon. But the earlier stages of the work of segregation are by underground waters, and if their part of the work were considered the ores would be classed as metamorphic. The iron precipitated is usually carried under ground as carbonates, but when oxygen is abundant oxidation takes place, the carbon dioxide is liberated, the ferric oxide unites with water, and limonite is then thrown down.

Iron Works.—In 1834 we have the beginning of the iron industry of Northern Indiana. A man by the name of A. M. Hurd came to the place where the city of Mishawaka now stands, and laid out a town about five by six blocks, which he called "St. Joseph Iron Works," and which was later incorporated under the present name. Hurd constructed a small wing dam at the head of the rapids on the St. Joseph River and dug a ditch for the purpose of carrying the water to a place where it could be utilized to furnish power. There he built a small smelting furnace and a mill. The necessary machinery, which consisted mainly of a large cast iron cylinder blower, was hauled through the woods from Detroit by oxen. The country to the south was heavily timbered and a number of practical furnace men and charcoal burners were attracted to the place from the furnace districts of Ohio. The ore used was the "bog ore," which was found in considerable quantities in several nearby localities. The farmers delivered the ore and charcoal to the furnace and were paid on the basis of one-fourth cash and three-fourths in goods from the company's store.

The only outlet for the products of the furnace was in the manufacture of iron castings, which were needed by the early settlers of the surrounding country, and as there were no such wares made in the west at any point, the various articles, kettles for household use, kettles for maple sugar making and larger ones for turning the ashes left after clearing the land by burning the timber into pot and pearl ashes, called pot-ash kettles; later stoves were made, and previous to the coming of railroads in this direction the merchant and home-makers for probably a hundred miles around came here for their wares. With the coming of the railroad—the present Lake Shore and Michigan Southern—all was changed, much of the iron work for this and other railroads was made and a period of prosperity followed. The business, after passing from the possession of Mr. Hurd, was owned by J. H. Orr, J. E. Hollister and John Niles. About 1858 the smelting of ore was discontinued, chiefly because of the high cost of charcoal.

About 1847 a second furnace was started, owned principally by Boston parties. It was not successful and in a few years the enterprise was abandoned. At an early date a forge was built for the manufacture of wrought iron directly from the native ore, and the product was hammered out by heavy tilt hammers, as this was before the time of rolling mills. With the introduction of rolled iron the business was abandoned.

The city of Mishawaka now has a population of about twelve thousand and its existence is probably due to the deposits of ore in the marshes of that vicinity.

In 1845 Messrs. French and Beers erected a Catalin forge in Rochester, on the Elkhart River, in the NORTHWEST northeast corner of Noble County. About the time the forge was completed, and before it was put in operation, the original proprietors sold to W. F. Lee of Mishawaka, A. D. Webster of Rochester, New York, and D. M. Beers of Newtown, Conn., who put the forge in blast, employing about sixty men in digging and hauling ore, burning and hauling charcoal and working the forge. About four hundred bushels of charcoal were burned in making one ton of bar iron from three tons of ore. The product was ten tons of bar iron per week, which was sold at $100 per ton. Ore diggers, colliers and common laborers were paid fifty cents per day and boarded, while "bloomers" and "hammersmen" received two dollars per day and board. The tract of land on Ore Prairie from which the ore was dug was then owned by Hon. Henry L. Ellsworth, of Lafayette, Ind., who received a royalty of twelve and a half cents per ton for all ore taken out. The firm continued in business until the spring of 1850, when they sold to Wood and Bromley of Lagrange, who carried it on a few years and abandoned the enterprise.

About the year 1850 a forge was started at Lima, Lagrange

County. The ore used was found along Pigeon River, west of Lima. This ore was worked into bar iron, which made a very good article and demanded a fair price. The ore being difficult of access, and charcoal increasing in price, the forge was abandoned about the time the Lake Shore and Michigan Southern Railroad placed this part of the country in quick and cheap communication with the iron manufacturers of Cleveland and Pittsburg.

New Iron and Steel Works.—The union of cheap coal and iron ore has attracted to the shores of Lake Michigan what will eventually be the largest and most complete iron and steel manufacturing plant in the world. The tract of land purchased by the United States Steel Corporation for the new industrial city of Gary, Ind., at Indiana Harbor, measures 2,793 acres and cost $1,926,065. On this is being erected not only the largest iron and steel plant, but also a city dependent upon it. The engineering skill, the designing and building of such a plant, will be an accomplishment that will rank with the great public works of the world.

The immediate erection and completion of a great rail-mill, with sufficient blast furnace and steel work capacity to provide for its requirements, and the installation of other finishing units as required, with their raw material accessories, is the scheme that has been adopted for the development of the plant of the Indiana Steel Company, a subsidiary company of the United States Steel Corporation. The rail-mill is to have a capacity of seventy-five thousand tons a month, or nine hundred thousand tons a year. The four blast furnaces are to have a daily output of 1,800 tons, and the twenty-eight open-hearth furnaces 3,000 tons. As the rail-mill will require nearly three thousand tons of steel per day, there will be no surplus and the pig output is also adjusted and provides for about 40 per cent. admixture of scrap. The blast furnaces under construction are in the center of the ultimate group of sixteen; and the two open-hearth units are similarly located in the group of six open-hearth plants, which will ultimately contain eighty-four furnaces. The stove and furnace stacks will be ninety feet high and will have a diameter of twenty-one feet and six inches. From these dimensions it is apparent that they have been designed with a view to the use of a fairly heavy percentage of fine ores. Gas-driven blowing engines will furnish air to the stacks. Gas engines for utilizing blast furnace gases are being introduced in old mills and are to be used on a large scale in the new plant. According to the "Iron Age" there are now under construction, and ordered by the Steel Corporation, gas engines aggregating a total of 102,000 horse-power, of which 44,000 horse-power will be in blowing engines, and 58,000 horse-power for the other purposes, chiefly for the generation of electric power. Only a few of these engines will be supplied with producer gas for special purposes; the rest, furnishing a total of 100,000 horse-power, will be operated with the gases from the blast furnaces, which would otherwise go to waste, with the exception of that portion which would be utilized in the hot blast stoves and under boilers.

There has been but very little done in the northern part of the State to determine the extent of the iron ore deposits. It would be impossible to place an estimate on the amount of ore that might be found during the progress of careful development. As stated above large quantities of ore have been found in the edges of the lakes and marshes. Many wells that have been put down in this area have passed through ore, while others do not show but a trace even in analysis of the water. In Dekalb County a vein of water found at a depth of eight to ten feet is colored, due largely to seepage from peat beds, and is slightly chalybeate, and at a depth of about forty feet from the surface there is a vein of water strongly chalybeate. At La Crosse most of the wells penetrate more or less iron ore and the water when analyzed shows iron. The ditches that have been made for the drainage of the Kankakee region have, in several places, cut through considerable beds of the ore. In cutting a ditch through the Wm. Henke farm, south of the Kankakee, a carload of bog ore was taken out and utilized in a blast furnace and is said to have shown an iron content of about 65 per cent.

The chief known deposits are in the Calumet region, especially in the vicinity of Furnessville, where masses of ore weighing hundreds of pounds have been unearthed. Along the Kankakee, extending back in places several miles, and along the river to its source in the marshes near South Bend, where much of the ore for the furnace at Mishawaka was found. In Ore Prairie, in Noble County, and along Pigeon Creek, in Lagrange County, is found the greatest abundance of ore in the eastern part of the region.

This region, outside of the manufacturing district, is chiefly an agricultural district, but in order to drain and reclaim the thousands of acres of marsh land, the main channels of the streams must be straigtened and deepened and the digging of a large number of lateral ditches through the swamps to the improved channels will be required.

These ditches will largely determine as to the amount of ore, and the coming of new blast furnaces, the scarcity of fuel, and the use of low-grade ores may lead to the development of these bog ore deposits.

SCOTT, CLARK AND FLOYD COUNTIES.

In the base of the knob shales immediately overlying the New Albany black shale are found several bands of kidney ore and iron stone, which can be found over a large area in the above-named counties. The ore outcrops in almost every ravine cut through the shales. The knob shale, when exposed, is readily weathered out and the iron ore washes down and accumulates along the valleys and streams. The ore, wherever found, is of the same general character and contains about 28 per cent metallic iron. As many as six to ten bands of the ore may be found in a vertical space of about twenty feet. The lower band is usually on a level with the drainage of the country. The bands will average from two to six inches in thickness and are separated from each other by from two to four feet of shale.

The iron ore deposits of Scott County are confined to Finley and Vienna Townships, and are seen at the head waters of Pigeon Roost Creek and along Kimberland Creek. The stratified iron stone with the kidney ore makes up several bands from 2 to 10 inches in thickness. Along Pigeon Roost and Big Ox Creeks and other streams of the iron-bearing shale is considerable pebbly iron-stone conglomerate gravel, which has been used on many of the improved roads.

In Clark County the principal bands of iron ore are found in the vicinity of Henryville. At one time a Mr. Stewart, who lived at Henryville and was the owner of large tracts of land containing this iron stone, offered to take a contract, at \$1.75 to \$2.00 per gross ton, to deliver on the cars at Henryville, from 100 to 200 tons of this iron ore per day, for a period of five or ten years. His offer, however, was not accepted.

About 1840, James Works, an ironmaster from Pennsylvania, examined the ores of this area and especially those found near Henryville, Clark County. He pronounced it good ore and made preparations to erect a furnace, but the project was finally abandoned. A little more than thirty years ago interest in these ores was again revived and several analyses were made. The chief value then supposed to be in these ores was mainly due to the amount of maganese shown by the analysis and it was thought if properly smelted would yield a highly manganiferous pig iron, if not a true spiegeleisen. Since the ore accumulated in the ravine it would be easy of access, and by the various railways passing through this area the ore would have a ready means of shipment to the blast furnaces then in operation in the State, unless new furnaces were built expressly to melt this ore, the question of cheap fuel being of chief importance in the selection of the locality.

The character and importance of this iron will be shown in the following analysis and sections. It is stated that in making the analysis the kidney ore was mostly used and the coating of red oxide was removed and the analysis made of the enclosed blue carbonate.

Analysis:

SAMPLE SCOTT COUNTY ORE.

Combined water	15.00
Silicic acid	14.00
Protoxide of iron	38.56
Sesquioxide of iron	3.01
Oxide of manganese	4.50
Carbonate of lime	2.02
Carbonate of manganese	.85
Sulphur	.05
Phosphoric acid	.50
Carbonic acid and loss	21.51

Total per cent of iron, 32.20.

SAMPLE FROM NORTH OF HENRYVILLE.

Moisture dried at 212°	0.500
Insoluble silicates	16.400
Carbonate of iron	49.400
Peroxide of iron	2.171
Manganese	2.500
Alumina	1.500
Carbonate of magnesia	14.000
Carbonate of lime	10.000
Sulphuric acid	0.686
Phosphoric acid	0.779
Loss and undetermined	1.744

Iron content of ten bands of ore, near Henryville. Bands numbered from top to bottom:

	Per cent.		*Per cent.*
Band No. 1	26.41	Band No. 6	29.74
Band No. 2	26.66	Band No. 7	29.23
Band No. 3	30.51	Band No. 8	27.17
Band No. 4	28.20	Band No. 9	28.00
Band No. 5	29.12	Band No. 10	28.48

Sections.—A vertical section on Pigeon Creek:

1.	Ash colored and ocherous clay	5 ft. 00 in.
2.	Shale containing 5 in. band of iron stone	5 ft. 00 in.
3.	Three to four feet shale with kidney ore	4 ft. 00 in.
4.	Band of iron stone	6 to 8 in.
5.	Shale 2 to 4 ft., with band of iron stone	8 to 10 in.
6.	Shale 3 to 5 ft., with band of iron stone	8 to 10 in.

Section outcrop one-half mile north of Lexington:

1.	Clay soil	3 to 12 ft.
2.	Black slate	4 to 7 ft.
3.	Oxide of iron	6 in.
4.	A light gray fossiliferous limestone	4 ft.
5.	Darker, fossiliferous limestone	8 ft.
6.	White limestone with fossils	6 ft.

Section three and one-half miles northwest of Henryville:

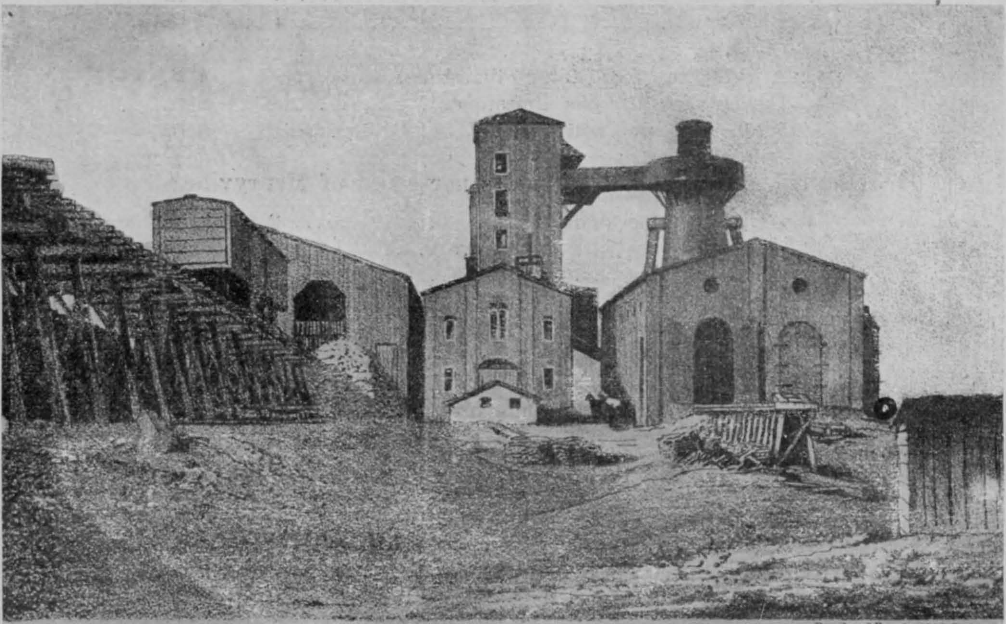
1.	Greenish blue shale	2 ft.	0 in.
2.	Band iron ore with kidney ore	0 ft.	5 in.
3.	Greenish blue shale	4 ft.	0 in.
4.	Band iron ore	0 ft.	5 in.
5.	Greenish blue shale	4 ft.	6 in.
6.	Band iron ore	0 ft.	6 in.
7.	Greenish blue shale	3 ft.	0 in.
8.	Band iron ore with kidney ore	0 ft.	8 in.
9.	Greenish shale	2 ft.	0 in.
10.	Band iron ore	0 ft.	8 in.
11.	Greenish shale	1 ft.	6 in.
12.	Band ore	0 ft.	5 in.
13.	Shales	3 ft.	0 in.
14.	Ferruginous limestone	2 ft.	6 in.
15.	New Albany black shale	6 ft.	0 in.
		31 ft.	6 in.

VIGO AND VERMILLION COUNTIES.

On the west side of the Wabash River in the bluish-gray shales are bands of clay iron stone and kidney ore concretions. Along the hillsides and in the ravine these pieces of ore are found in considerable quantities. They were formerly found in sufficient quantities to justify their being gathered up and carted to the Vigo Blast Furnace at Terre Haute, to be mixed with the Missouri ores and smelted. This furnace was the last one of the old group of Indiana furnaces to go out of blast; it ceased operation about 1895.

The old Indiana Furnace in Vermillion County, when in blast, obtained its supply of iron ore from these shales. It experienced no difficulty in finding an abundant supply of ore, though it was in blast for a number of years and consumed daily from thirty to forty tons of ore. The outer wall of the stack was built of sandstone and about forty feet high and nine feet across the boshes.

Plate XX.



Braden & Burford Lith Ind.

VIGO BLAST FURNACE.

Terre Haute, Ind.

The daily make of metal was about nine tons. The furnace used charcoal for fuel and on account of the growing scarcity of timber for charcoal and the distance from railroad facilities the furnace went out of blast in 1859.

An attempt was once made to use the coal in this section in the furnace and "a number of kettles were cast from the iron produced, but the metal proved brittle, probably from the presence of sulphur," and no further use of the coal was made for smelting purposes.

The principal places where the ore is found in the greatest abundance are in the vicinity of Tecumseh, or Durkey's Ferry, on the west side of the river, about six miles north of Terre Haute and along the line of the new branch of the Southern Indiana Railroad and extending up into Vermillion County along Brouillet's Creek and from the mouth of Little Vermillion, at various places along the Wabash to the mouth of the Big Vermillion, but the more abundant deposits lie just beyond the Illinois line.

At Durkey's Ferry, in some of the ironstone nodules, fine specimens of fossil ferns have been found. On Little Vermillion compact brown ironstone is found containing fish remains, and at Hanging Rock many iron ore concretions are found containing fossil plants.

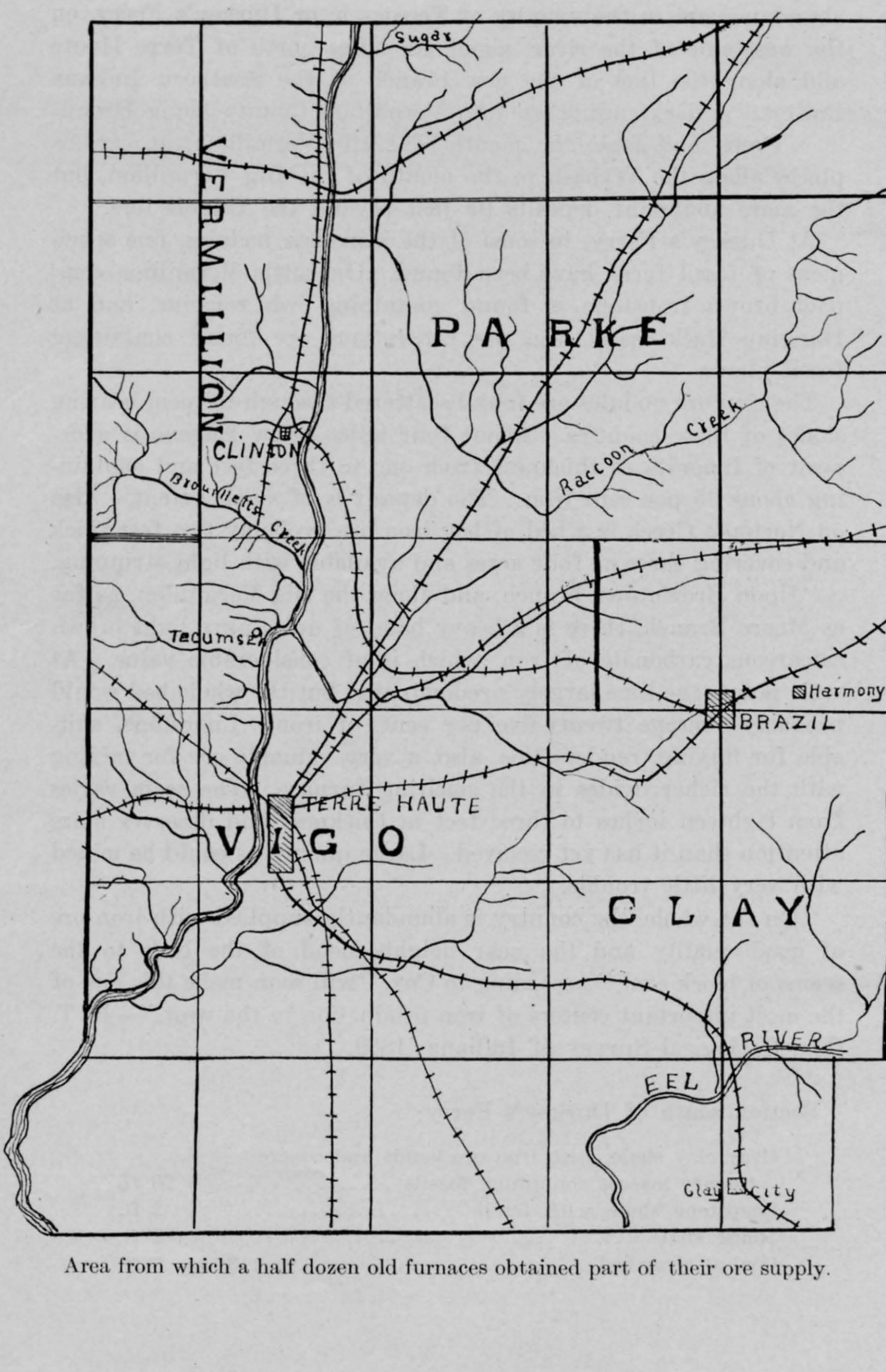
The iron ore nodules are found scattered through the coal bearing shales of these counties. About four miles below Eugene is a deposit of limonite in thickness from one to three feet and containing about 35 per cent iron. The deposit is of small extent. Also on Norton's Creek is a bed of bog iron ore probably two feet thick and covering three or four acres and available with light stripping.

"Upon Browntown branch, and along the Big Vermillion, as far as Moore Branch, there is a heavy band of quite pure light brown calcareous carbonate of iron, which is of considerable value. At some points the lime largely predominates, but the whole bed would probably average twenty-five per cent. of iron. Limestone, suitable for fluxing, renders this, also, a very valuable ore for mixing with the richer oxides in the smelting furnace. The seam varies from eighteen inches to three feet in thickness and deserves more attention than it has yet received. Large quantities could be mined with very little trouble.

"On the whole, the country is abundantly supplied with iron ore of good quality and the near neighborhood of the beds to the seams of block coal," according to Cox, "will soon make this one of the most important centers of iron production in the west."—E. T. Cox, Geological Survey of Indiana, 1869.

Section south of Durkey's Ferry:

Gray clay shale, with iron ore bands and concretionary masses containing fossils	20 ft.
Soapstone shale with fossils	2 ft.
Black shale	2 ft.
Coal at river bed	3 to 5 ft.



Area from which a half dozen old furnaces obtained part of their ore supply.

Section near the site of the Indiana Furnace upon Coal Creek, a tributary to Brouillet's Creek:

Greenish sand shale, with iron ore bands and kidney iron ore	20 ft.
Drab clay shales	5 to 20 ft.
Shaly coal	1 to 3 ft.
Coal	2 to 4 ft.
Fire clay	6 ft.
Sand shales	10 to 12 ft.
Limestone	1 to 2 ft.

Section near Newport on Little Vermillion:

Clay shales with iron-stone	3 to 5 ft.
Clay shales	6 to 5 ft.
Coal	8 to 20 ft.
Fire clay	4 to 6 ft.
Shales	25 to 40 ft.
Iron-stone and nodules in shale	3 to 5 ft.

Section on river bank near Eugene:

Surface and fire clay	2 ft.
Black shale	2 ft.
Fossiliferous iron-stone and shale	2 ft.
Black shale	6 in.
Slaty shale with cannel coal	1 ft.
Coal	1 ft.
Sandstone	1 ft.
Fire clay grading to sand shale	7 ft.

Section upon Browntown Branch:

Black calcareous ore	1 to 2 ft.
Black shale	4 to 5 ft.
Fire clay	1 ft.
Shaly sandstone	6 to 8 ft.
Compact sandstone	9 to 10 ft.
Shaly sandstone	1 to 2 ft.
Iron ore band	2 in.
Sand shale	10 ft.
Shaly iron ore with fossils	18 in.
Shaly sandstone with some ore	40 ft.

The iron ores would give an average analysis of about 33 per cent. But as will be seen from the above description and the sections given these ores are not now of economic importance, yet they are of geological importance and of special interest to fossil seekers.

PARKE AND FOUNTAIN COUNTIES.

The iron ores of these counties, although not of sufficient abundance to supply blast furnaces, have been carefully investigated several times. It is much the same as that found in the counties described above. Where the creeks and branches cut through the shales at the base of the coal measures several bands of low-grade iron ore are exposed to view and the beds of the streams are in places almost covered with pieces of ore that have been washed down from the shales. The principal places where these iron ores are found are along Coal Creek and in the bluffs facing the Wabash River.

Concerning the ores of Parke County, Prof. Cox says, in his Geological Report: "The banded and kidney ores are abundant throughout the county, and they are estimated to yield about 30-33 per cent. metallic iron. Very good-natured clay ores are also found at different creeks of this and other counties and may be classified in the following manner:

1. The impure carbonate of iron, including clay ironstones, in flattened spheroidal masses and in bands, more or less continuous, associated with argillaceous shales.
2. Brown sesquioxides or limonites.
3. Silicious oxides.

The ores indicate sufficient richness to justify smelting, whenever facilities can be had for cheap and ready transportation. Especially do they show that the country has the desirable ore for admixture with those of Lake Superior and Missouri."

Section on Sand Creek, Parke County:

Surface	10 ft.
Sandstone and shale	8 ft.
Fossiliferous limestone	3 ft.
Ivory shale	1 ft.
Coal	3 ft.
Shale with bands, iron ore	25 ft.
Coal	4 ft.
Fire clay	3 ft.
Sandstone	5 ft.
Sand shales with several bands iron ore	20 ft.
Coal	6 in.
Soft, reddish sandstone down below bed of creek	15 ft.

Section on river bluff, southwest corner of Fountain County, beginning 30 feet from surface:

Coal	1 ft.	6 in.
Fire clay	3 ft.	6 in.
Shale with iron ore	8 ft.	0 in.
Iron ore concretion	0 ft.	6 in.
Black shale	2 ft.	0 in.
Shaly coal	1 ft.	6 in.
Sandy fire clay	2 ft.	6 in.
Shale with iron ore concretions	10 ft.	0 in.
Band iron ore	0 ft.	4 in.
Black shale	1 ft.	8 in.
Coal	1 ft.	8 in.
Fire clay	6 ft.	0 in.
Shale with ore	2 ft.	0 in.
Fossiliferous limestone	4 ft.	10 in.
Shaly coal	4 ft.	0 in.
Fire clay	4 ft.	0 in.
Soft white sandstone	2 ft.	0 in.
Siliceous iron ore	0 ft.	10 in.
Sandstone	6 ft.	0 in.

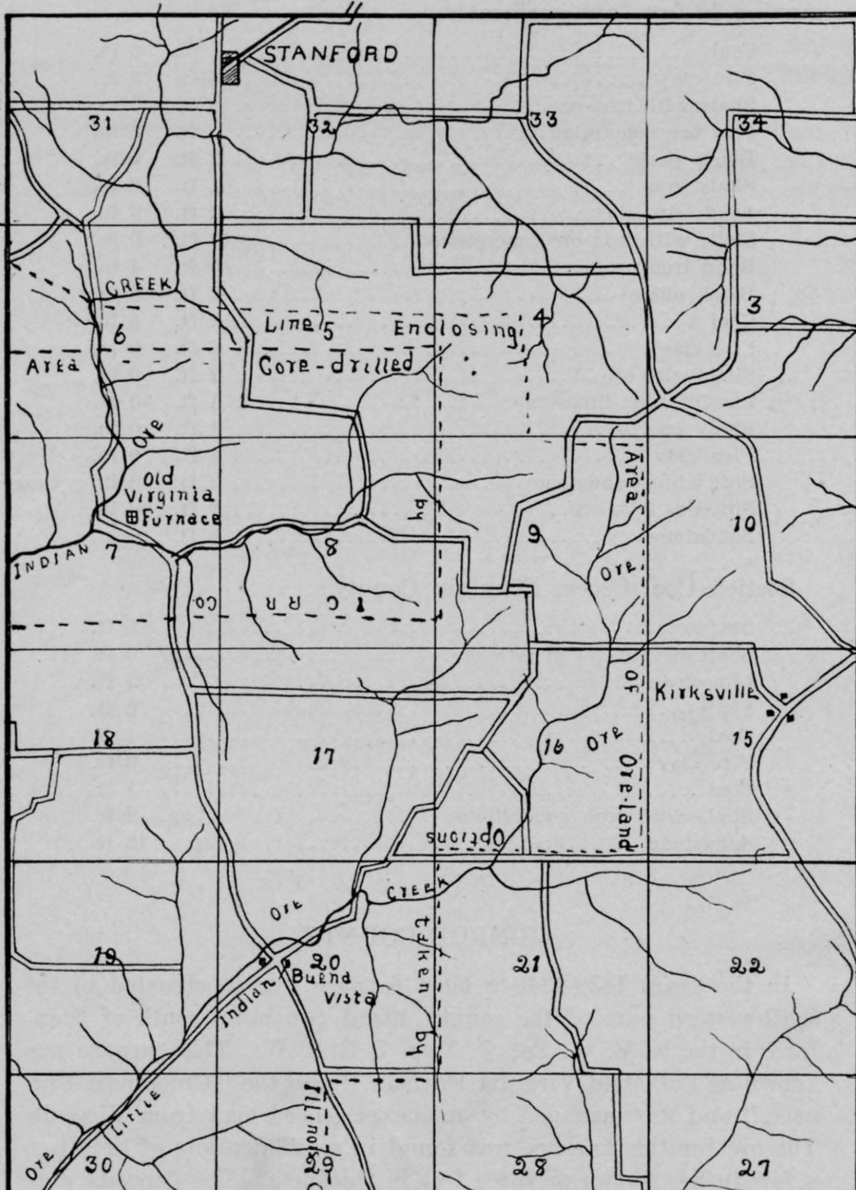
Section Coal Creek, Fountain County:

Surface	5 ft.
Shale with iron concretions	6 ft.
Limestone	2 ft.
Shale	8 ft.
Coal	1 ft.
Fire clay	3 ft.
Coal	1 ft.
Shale with iron concretions	2 ft.
Sandstone	12 ft.

MONROE COUNTY.

In the years 1839-1840 a blast furnace was constructed in the southwestern part of the county, about two miles south of Stanford, in the N. E. ¼, Sec. 7, Twp. 7, R. 2. W. This furnace was known as the "Old Virginia Furnace," also the "Cincinnati Furnace," and was managed by an inexperienced man from Virginia. The ore for this furnace was found in small deposits of ore from a few inches to two or three feet in thickness. The deposits were also of small lateral extent and consisted chiefly of ironstone concretions and highly silicious banded ore. The location of the furnace and the deposits are marked on the map. One of these was about one-half mile northeast of the furnace and the other about

MONROE COUNTY AREA.



R. 2 W.

three miles east. Small quantities were taken from several points along Indian Creek. The greater part of the ore, however, for this furnace was brought from the edge of Greene County, in the vicinity of the little town of Cincinnati. The ore was taken from the hillsides and streams by the farmers and hauled to the furnace. Charcoal was used as fuel and the preparation of this gave employment to a number of men. An abundant supply of limestone for flux was found in the surrounding hills about fifty feet above the elevation of the furnace.

The furnace would be in blast for a few weeks and then shut down for some time for repairs and to await a supply of ore.

The best per day production was three tons pig iron, the average yield for the time running being about one and a half tons per day. The iron was sold at Louisville for twenty dollars per ton. On account of inexperienced men and difficulty in getting the ore and fuel, the furnace failed to repay the promoters and was only in operation a few years.

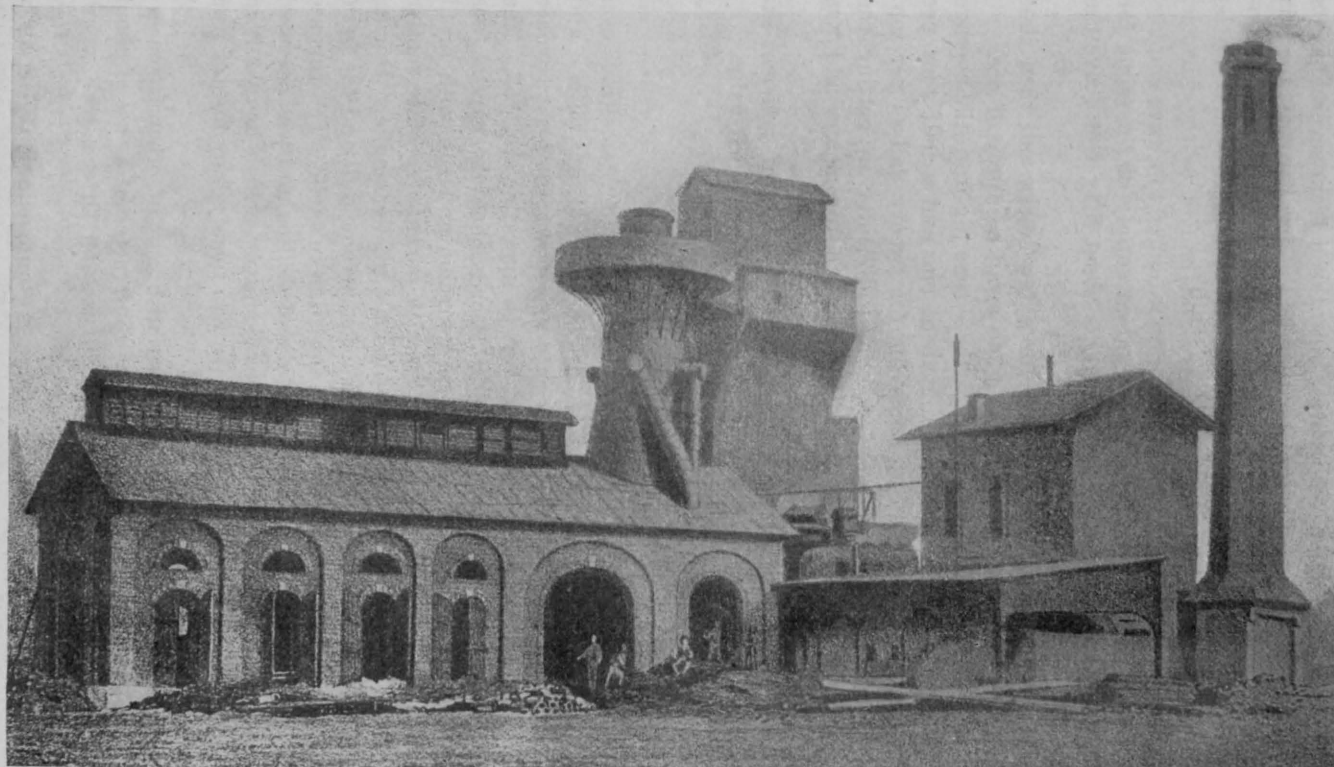
These deposits of ore in Monroe County are not of sufficient extent to be considered of any commercial and economic value.

CLAY COUNTY.

The introduction of the Brazil block coal for smelting iron led to the establishment of furnaces, rolling mills and foundries. The pioneer of these enterprises was the blast furnace in Brazil. This was erected and put in operation in 1867. The stockholders were Indianapolis and Brazil men; the capital was $150,000. The furnace was put in operation and run with profit for a short time, when it shut down with perhaps no other motive than for the larger stockholders to gobble up the smaller. During the period of its idleness the iron market became dull and the price of pig iron declined as a result of reduction in tariff. The furnace fell into the hands of Messrs. Garlic and Collins and was operated later by the Central Iron and Steel Company, which bought it in 1882 for about $20,000. The capacity was twenty-four tons of iron per day.

The original success led to the establishment of other furnaces: in Knightsville a double furnace was constructed at a cost of about $200,000, in 1867-68; the Masten Furnace on Otter Creek, north of Brazil, using chiefly native ore; the "Star" or "Planet" furnace, east of Harmony, using native ore and using fifty or sixty teams to haul the ore to the furnace. These furnaces were built

Plate XXI.



Brazil Furnace at Brazil, Clay County, Indiana.

on the theory that the location of all such works should be in the vicinity of the fuel, it being more practical to ship most of the ore. These furnaces have all long since gone down.

The five blast furnaces in Clay County made pig iron with raw block coal. "They all run upon the hot blast principle, and the blast is heated in gas ovens by the waste gas brought from the top of the stack. The total working capital employed at these furnaces was about $600,000. Combined they consumed daily:

300 tons "Block" coal.

150 tons ore—chiefly from Lake Superior and Iron Mountain.

50 tons of limestone for flux.

"The daily make of iron was about 110 tons, worth on an average, at the furnaces, forty dollars per ton, including all grades. The total value of each day's run of iron is, therefore, four thousand four hundred dollars, or about one and a half million dollars per annum, after allowing for mishaps and loss from accidents. The number of men employed at these furnaces, not including coal miners, was about two hundred.

"All the furnace companies own collieries and give employment to a great many more men who were engaged in mining 'block' coal for the furnaces, also for the market."

Although the iron ores found in this region were used to some extent it was found that the native ore was more expensive in proportion to the quality of iron it contains than the ore from either Lake Superior or Missouri. When the home ores were being used it was hauled in by the farmers and when the furnace capacity was increased so that the furnace owners called for 200 tons of ore per day the farmers were alarmed and were afraid to attempt to furnish the required amount.

Section of bore near Knightsville:

Surface clay	7 ft.	6 in.
Sandy clay	7 ft.	0 in.
Hard pan	1 ft.	0 in.
Brown sandstone	5 ft.	2 in.
Fire clay	1 ft.	2 in.
Blue shale	2 ft.	2 in.
Iron ore	0 ft.	3 in.
Blue shale	2 ft.	2 in.
Iron ore	0 ft.	1 in.
Blue shale	0 ft.	7 in.
Shale with sandstone	6 ft.	6 in.
	35 ft.	4 in.

Plate XXII.

LAFAYETTE FURNACE. Clay Co.

B.F. Master Supt

Section three and one-half miles southeast of Brazil, Section 10, Township 12, Range 6 W.:

Surface	11 ft.	0 in.
Hardpan	10 ft.	6 in.
Gray slate	4 ft.	0 in.
Shale with ore concretions	3 ft.	0 in.
Black slate	1 ft.	6 in.
Coal	3 ft.	6 in.
	33 ft.	6 in.

Section four miles west of Brazil, near Staunton:

Shale with iron concretions	20 ft.	0 in.
Coal	1 ft.	8 in.
Sandstone	20 ft.	0 in.
Shale	4 ft.	0 in.
Coal	2 ft.	6 in.
Shale	46 ft.	0 in.
Coal	2 ft.	6 in.
	96 ft.	8 in.

ORANGE COUNTY.

The topographical features of this county are varied. The southern and western part is very hilly. In many of these hills, at the base of the conglomerate sandstone and above the "whetstone" grit, is found considerable deposits of silicious iron ore. In some localities it is comparatively free from silica. There are numerous deposits from two to four feet in thickness on the outcrop, but of small length and lateral extent. This county is on the eastern edge of the chief ore area, and its ore deposits in themselves are of little economic value, but if furnaces should be built for smelting the ores of adjoining counties, the ores of Orange County could be utilized and would largely increase the tonnage of Indiana ores. No analysis of these ores was made expressly for this report, but when the blast furnace at Shoals, Martin County, was in operation tests were made of the ore found in section 8, township 1 north, range 2 west, and showed an iron content of 35 per cent. to 50 per cent., according to material taken; the selected specimens giving the higher percentage.

LAWRENCE COUNTY.

This county also is on the eastern edge of the iron area of the State. The western part is also similar in its physical features to the part of Orange county described. The southwestern part, south of the river to the county line, consists chiefly of the the same formations to be found in the iron district of Martin County. The area containing workable deposits of iron is very limited, although there are a few deposits that may prove of value. The part of the county south of the river showing indications of iron was worked over in a limited way, but no excavations or facings were made at the outcrops to determine the extent and thickness of the deposits. The largest deposit known is in section 21, township 4, range 2 W, and is a deposit of brown ore underlying the bed of porcelain clay which was formerly worked. The ore was also smelted in the Shoals blast furnace with very good results, the smelting requiring but little fuel and flux and made an excellent quality of pig iron. The ore varies in thickness from a few inches to over four feet. Other deposits, or rather a continuation of the above mentioned deposit, since thin connecting outcrops can be traced along the hillsides, are to be found farther to the north and east, and in many places there is no white clay above the ore.

The section given below and the description of the clay and ore deposits are taken from Geological Report of Indiana by E. T. Cox, 1874. This quotation will be of interest and importance in the consideration of these ores. The section was made at the clay mine when it was well opened for work.

Section of the Porcelain clay mine:

Soil and subsoil	3 ft.
Coal measure conglomerate	100 ft.
Porcelain clay-replacing limestone	6 ft.
Iron ore	4 ft.
Marly and siliceous shale	4 ft.
Chester sandstone	50 ft.
Archimedes limestone	17 ft.
Marly shale	10 ft.
Chester sandstone	40 ft.
Limestone	6 ft.
Coal	1 to 3 in.
St. Louis limestone, to low water mark in White River	150 ft.

"It will be seen from the above section that the clay lies immediately beneath the Millstone grit or pebbly conglomerate of the coal measures and here occupies the place of a bed of Archimedes limestone which is seen in situ about two miles southeast of the mine. The overlying sandstone is very ferruginous and the base, where exposed to the weather, has decomposd and covered the clay in places to a depth of eight or ten feet with ferruginous sand and pebbles. There is a constant oozing of water from this sandstone which has, no doubt, played an important part in the chemistry of the clay and hematite deposit, for, though similar in its chemical composition to kaolin, this clay differs physically and owes its origin to an entirely distinct set of causes and effects. While the former is derived from the decomposition of the feldspar of feldspathic rocks, such as granite, porphyry, etc., the porcelain clay of Lawrence County has resulted from the decomposition, by chemical waters, of a bed of limestone and the mutual interchange of molecules in the solution, brought about by chemical precipitation and affinity. Where cavities existed in the limestone at the base of the strata, there the chalyebeate waters found the oxygen to change the carbonate into sesquioxide of iron, which finally filled up the cavity. In places, you can trace the passage of the ferruginous water along irregular joints in the clay bed, by the iron-stained path which it has left, to the brown hematite ore which lies in a mass at the bottom. The largest beds of hydrated sesquioxide of iron, both in Europe and America, are found at the base of the Millstone grit and filling up cavities in the cavernous sub-carboniferous limestone."

Recent developments from core drilling and field explorations show that the formations throughout this area are not continuous in uniform thickness, but are much broken—formations found in one place may be entirely missing only a short distance away. The section and description given by Mr. Cox would therefore appear to be much in error, since his section covers a lateral distance of more than two miles; and the origin of the clay and ore deposits would probably be due to other sources than those described.

Mr. Cox gives several analyses of samples of the ore from the clay bank deposits. Since no analyses were made of this or for this report I give below the average analysis taken from the tables by Mr. Cox. The samples taken for these analyses were, undoubtedly, made from selected specimens, as it will be seen that the percentage of metallic iron is much higher than other Indiana ores have shown:

Hygroscopic water	2.32
Combined water	8.50
Insoluble silicates	3.50
Sesquioxide of iron	79.50
Sesquioxide of manganese	2.00
Alumina	2.00
Magnesia carbonate	.426
Lime carbonate	.555
Phosphoric acid	.139
Sulphur	trace

It would be impossible to place an estimate upon the tonnage of merchantable ore in the above named deposits, until further developments have been made, both by excavations and core drilling. But there is in all probability enough ore in these deposits to justify careful and serious investigation.

There is another deposit in the southern part of section 31, and the northern part of section 6, T. 3, N., R. 2 W., with ore similar to that described. This deposit has not been faced, but there are two sides exposed and it probably contains about 37,000 tons. It could be mined with very little difficulty.

North of the river in section 28, Twp. 5 N., Range 2 W., are other deposits of red iron ore. The principal developments made here were a number of years ago by the "Southern Indiana Iron Companies," and deposits are reported varying in thickness from two to four feet, and covering a considerable area. About the time the old furnace ceased operation, the "Shoals Iron Company" were arranging to build a tramway from the mine to White River, thence making use of water transportation to their furnace at Shoals. Analyses of ores from these deposits show the following average composition:

Moisture and combined water	13.00
Insoluble silicates	0.90
Ferric oxide	84.89
Alumina	trace
Manganese	none
Phosphoric acid	.145
Carbonate of lime	1.00
Metallic iron	58.00

Analysis from E. R. Cox, 1873-1874.

GREENE COUNTY.

Greene County, ranking second in the State as to extent and value of its iron ore deposits, is situated as follows in reference to the other counties of the same ore area: On the north it is bounded by Clay and Owen; on the east by Monroe and Lawrence; on the south by Martin, Daviess and Knox counties, and on the west by Sullivan County.

The West Fork of White River, which runs in a southwestern course through the county, dividing it into two almost equal parts, is the principal stream of water. The main tributaries of White River in the county are: Eel River, Lotta's Creek, and Black Creek on the west side; and Richland Creek, Doan's Creek and First Creek on the east side. The southeastern portion of the county is drained by Indian Creek, which empties into the East Fork of White River.

The topography of the part of the county to the east of the river is more rugged than that to the west. Hills rise from 100 feet to 300 feet in height; whereas to the west of the river, with the exception of a ridge running from Eel River, on the north to White River on the south, in Fair Play Township, and passing a short distance to the west of Worthington, the county is generally level, or slightly undulating, a considerable part of it being prairie. This western portion is the great coal producing area of the county, and it is also the chief agricultural district. The valuable resources of the eastern part are more limited. Thin bedded coals are found; the limestones and sandstones are of little economic importance except for local use. There are extensive beds of shale, which may prove of value for the making of cement and other products of shale. Most of the fire clays are rendered worthless by the large percentage of iron which they contain. The chief interest at the present time is in the iron ore deposits of this part of the county.

Developments.—From 1840-1860, the iron ore deposits of the county were worked in a limited way and utilized in two blast furnaces built expressly for smelting these ores. Previous to the autumn of 1869, the time of completion of the Indianapolis & Vincennes Railroad, this county was without a direct practicable means of communication with the distant centers of trade. Consequently up to that time there was no incentive or inducement offered to its citizens to attempt any development of its resources, and for the same reason any works that were put in operation soon came to a standstill. Geologists and prospectors had but little to guide in their investigations beyond the obscure natural outcrops of the strata, and a few imperfect openings of coal and iron mines—the former of which were only worked to supply the limited wants of the immediate neighborhood.

Various attempts have been made to revive an interest in the iron ores of the county, but it was not until 1902 that any real prospecting began. In that year the promoters of the Indianapolis Southern Railroad secured options on several thousand acres and securing the services of an expert mineralogist and geologist, began prospecting for ore. The surface outcrops were investigated and excavations and cuts were made. Many prospect holes were put down with the core-drill, and although the company will give out no information, they claim to have found deposits of rich ore and pyrites apparently of great extent.

While there are considerable deposits of workable iron ore in Greene County, the actual extent of the deposits has at times been greatly exaggerated. In some cases large deposits of red shale have been classed as rich deposits of ore. Anyone familiar with the geology of the region will not expect to find large and continuous deposits. Nevertheless the ores that are found show a fairly high percentage of iron as compared with other Indiana ores, and since some of the outcrops show a thickness of several feet, it is to be hoped that the core drill records will show the existence of other deposits and depth to the outcropping bodies of sufficient importance to justify greater developments at an early date.

The Richland Furnace.—The Richland furnace was built by Andrew Downey and went into blast about 1841. It was located in section 25, T. 7 N., R 4 W., near where Ore Branch empties into Richland Creek.

The furnace stack was about 45 feet high and nine feet across the boshes. Charcoal was used as fuel and about nine tons of pig iron were produced daily. Some of the iron was made into hollow wares, stoves, machinery, etc., but most of the pig iron was marketed at Louisville. The iron had to be hauled to Mitchell and be shipped to Louisville, or else hauled all the way in wagons, the latter being more economical. Although the iron sold for $26 per ton, about $20 was used in the transportation. Hence the cause assigned for the blowing out of the old furnace was the want of a suitable and economical means of getting the pig iron to market. It went out of blast in 1858 or 1859.

The other furnace using the Greene County ores was the old Virginia furnace located in the western edge of Monroe County, and is described under that county. The pig iron from this furnace was also hauled to Louisville. The furnace was poorly constructed and "the only wonder is that it made pig iron at all." There are to be found as relics in the homes of some of the citizens a few bars of the pig iron made from these ores. In appearance it was a very good quality of iron.

The following from the report of Prof. E. T. Cox, 1869, on the iron ores of Greene County, is here copied for comparison of analysis, location of deposits, value and uses of the ore and the origin of the deposits:

"It is at the junction of the conglomerate with the sub-carboniferous limestone that we find the great repository of limonite ores in this county, and, in fact, it forms the common horizon of this variety of iron in most of the western states. The ore lies in pockets of various dimensions, and owes its origin in most cases, to a metamorphism of the surrounding rocks, produced by the permeating of mineral waters that are strongly charged with protoxide of iron.

"On Ore Branch, section 22, town. 7, range 4 west, on Mr. Heaton's land, the base of the conglomerate has been completely changed by this process into a siliceous ore that is rich in iron to the depth of ten or twelve feet. Similar ores are seen on sections 21 and 28 of the same township and range; also in the greatest abundance at Mr. Law's place, on sections 4 and 9, township 7, range 6, where it can not be less than twenty-five or thirty feet in thickness, and great blocks lie scattered over the side of the ridge; it is in abundance also, on section 12, of the same township and range, and in the neighborhood of Owensboro in the southeast part of the county.

"The principal ore used at the Richland blast furnace, near Bloomfield, from Ore Branch of Plummer's Creek, forms a bench on each side of the ravine, and appears to lie between the massive ore and the subcarboniferous limestone which shows itself in the bottom near by. An excavation was made during my stay in the county, to show the thickness of the ore bed, which went to the depth of six feet, at which point the work was stopped without reaching the bottom of the deposit.

"Capt. M. H. Shryer, of Bloomfield, who frequently saw this bed of ore at the time it was being worked for the blast furnace, assures me that the deposit is fully nine feet in thickness. It lies in kidney-shaped masses in a matrix of ferruginous clay, and contains less silica than the massive ore. Characteristic samples of this kidney ore and of the massive siliceous block ore from the Richland furnace ore banks, were analyzed, and the following results were obtained:

'Kidney Ore' (limonite), specific gravity 2.583.

Loss by ignition, water and organic matter, mostly water	11.50
Insoluble silicates	17.00
Sesquioxide of iron, with some protoxide and a trace of manganese	56.00
Alumina	2.00
Carbonate of lime	10.00
Magnesia	3.50
	100.00

Giving 39.20 per cent. of iron.

This ore contains a large amount of lime, and will make an excellent quality of metal, and when roasted the percentage of metal will be increased to 45.42 per cent. Specimens of pig iron made from this ore were found at the furnace and have every appearance of being the best quality of mill iron.

"An analysis of the siliceous 'block ore' gave the following result:

Specific gravity, 2.585-2.694.

Loss by ignition, water	7.50
Insoluble silicates	34.00
Sesquioxide of iron	54.73
Alumina	2.50
Manganese	1.14
Lime	.12
Magnesia	.03
	100.02

Giving 38.31 per cent. of iron.

It was tested for sulphur and phosphorous, but found no trace. Two hundred grains of this siliceous ore, mixed with 50 grains of limestone, were fused in a Hessian crucible, and a button of iron was obtained that weighed 76 grains, equal to 38 per cent.; very nearly the same result as obtained by the humid analysis. The button indicated a very good quality of iron, slightly malleable, and gave a semi-crystalline fracture. The roasted ore would yield fully 40 per cent. of iron in the blast furnace, and on account of the manganese which it contains it is admirably adapted for the manufacture of steel, either by the Bessemer process or in the puddling furnace. Iron made from these ores alone will possess cold-short properties, but by mixing them in the proper proportions, with the red-short specular and magnetic ores from Missouri and Lake Superior, a neutral iron may be made."

The Ore Map.—The ore map accompanying this report shows the area over which the most careful investigation was made. It is not to be understood from the map that the entire area under the ore markings is covered by workable ore deposits. The area includes the chief deposits, which in most cases are noted on the map by special markings, and it also includes the area over which more or less iron ore is scattered, showing the possibility of a deposit near by. The map then is more of a guide to lead to the finding of deposits than a real index of known deposits. The existence of deposits outside of the area mapped may have been found in the core-drilling. A few small deposits are known farther west and south along the river, and the surface in many places shows very good indications of iron and developments may show the presence of some workable deposits. The area mapped covers the chief iron bearing localities.

The Ore Deposits.

In Greene County the known workable deposits of iron ore are to be found chiefly along Ore Branch, Richland Creek, Plummer's Creek and in the vicinity of Cincinnati. Some of these deposits will be described and the analysis appended.

Richland Furnace Ore Bank No. 1.—This deposit lies along the slope of the ridge just south of the old furnace location, on Ore Branch. The deposit is of kidney ore intermixed with much clay and broken sandstone. The total thickness is 20-25 feet, but the ore would aggregate but a few feet. This would now hardly be considered workable, although considerable ore from the bank was used in the Richland furnace. The samples analyzed show an average iron content of 37.65 per cent. This of course does not include any of the impurities imbedded with the ore. In the table of analysis the sample marks are No. 6 and No. 11. The complete analyses are given in the table, and they would be a fair average for most of the kidney ores of the county.

Furnace Bank No. 2.—Located in the southwest ¼, section 25, township 7 north, range 5 west, about 40 rods southwest of old furnace site. It is 65 feet above drainage. Elevation 565 feet. At the creek level is the outcrop of a thin bed of coal.

This iron ore is very siliceous. It is in a massive deposit but is very porous. The excavation, which did not reach the bottom, shows five feet of ore; it is probably six feet or more in thickness on the outcrop. The first drilling was made near the edge of the deposit, then two more were put down, one about 15 rods to the southwest, the third about the same distance to the southeast, and the fourth was near the first and was drilled at an angle, i. e. the drill was set perpendicular to the slope of the hill. The order of succession of these borings would indicate that the deposit was of small dimensions and as it thinned out back in the ridge it raised with the slope of the ridge. The deposit probably does not have a backward extent of more than 50 feet of workable ore. This deposit would yield about 8,000 tons of ore. It shows an iron content of 40.36 per cent. In the table of analysis the sample marks are No. 7 and No. 12.

No. 3, Cincinnati Ore.—In the vicinity of the little town of Cincinnati, in the eastern part of the county, the ground in many places is profusely covered over with fragments of ore, even on the tops and slopes of the highest ridges. About two and a half miles northeast of the town is a U. S. G. S. B. M., marked 853 feet. The mark is on a steel plate imbedded in a large piece of sandstone at the top of the ridge. Ore is found at this level, but there are no workable deposits.

On the east side of Cincinnati the ore outcrops in the shale along the sides of the ridge, and these outcrops follow around the ridge to the south of the town and more or less ore is found fringing the hills to the west and also to the north. The elevation of the town is a little lower than the surrounding hills. The elevation marked on a telephone pole by the store at the turn of the road is 825 feet. Another U. S. B. M. at an elevation of 880 feet is marked on a steel post about half a mile south of Cincinnati at a fork in the roads.

On the Starling Hudson farm in the southwest 1/4 of section 28, south of Cincinnati, is to be found considerable ore intermixed with the shale. This deposit of concretionary ore covers about forty acres. It is to be found in a thickness of more than ten feet in some places, but in no compactness that would be considered a workable ore. It is, however, very interesting geologically. At an elevation of 775 feet a thin bed of very fossiliferous limestone outcrops. Above this the ore is a constituent of the shales and sandstone; below the ledge of limestone the ore is concretionary and contains fossils or fragments of fossils, which have been replaced from the limestone fossils.

Deposit No. 4.—On Anthony Williams' land, northeast 1/4 southeast 1/4, section 21, township 7 north, range 4 west, is a deposit with an average thickness of five feet and has an exposed frontage of 250 feet. This is a brown, highly siliceous ore, which owes its origin to the filling of the sandstone with iron from mineral charged waters. Three drill holes were put down on the low ridge above the deposit.

Plate XXIII.

U. S. B. M., 853 feet, two and a half miles northeast of Cincinnati. Marking the top of the highest ridges. Weathered fragments of ore are found at this level.

Fossiliferous limestone outcrop and concretionary ore described under deposit No. 3.

Plate XXIV.

Concretionary ore intermixed with shale.

Another view of same deposit. Starling Hudson Farm, southwest of Cincinnati.

Across the road is another deposit of red hematite, which is in compact nodular masses imbedded in the clay. The excavation shows over five feet of this ore.

On the Miller farm, southwest of Williams's, ore similar to the above is also found.

In the table of analyses sample No. 1 was taken from the siliceous ore, and sample No. 3 was from the red hematite deposit, but does not include the clay, and sample marked No. 10 is from another outcrop of the siliceous deposit on the southeastern point of the hill about forty rods from the first deposit.

Deposit No. 5.—Southwest 1/4 of section 22, just east of the above deposits, is another opening from which ore was taken in the early days of the iron industry. It is a contination of the deposit of red ore, but probably contains less clay. The hills do not rise to great height above these ores, and both deposits would require on the average about fifteen feet of stripping. Samples Nos. 4 and 9 show the iron content.

Deposit No. 6.—On the John Bryan land, west side of section 9, township 7 north, range 4 west, is a deposit of red siliceous ore exposed on the south side of the ridge facing Richland Creek.

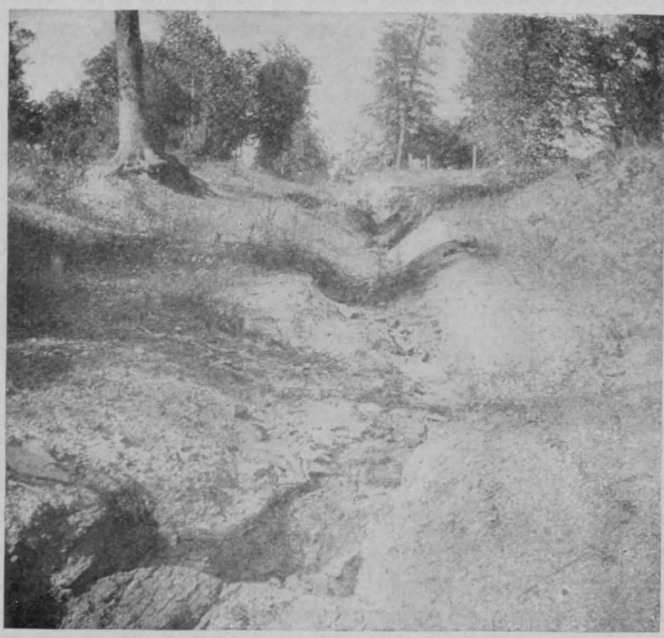
The deposit is about 40 feet above drainage and at an elevation of 600 feet. The maximum thickness is about 15 feet, and it has a frontage of more than 500 feet, but the backward extent is small, as the ridge is narrow and but little trace of ore is to be found on the opposite side. The tonnage would probably amount to about 25,000 tons. A vertical section of the ridge would be as follows:

Sandstone and clay with glacial material	15 ft.
Sandstone	25 ft.
Iron ore	15 ft.
Sandstone	35 ft.
Limestone down to creek	10 ft.

The analyses show an iron content of 42.01 per cent. The sample mark is No. 5.

Deposit No. 7.—Adius B. Hayes's land, section 16, township 7 north, range 4 west. Along the sides of the ravines are large accumulations of kidney ore, some pieces weighing hundreds of pounds. These shales are full of these ores. In the stream below the shales is a ledge of siliceous ore due to the filling of the sandstone with iron. Only a short distance back in the ledge the iron content is to be found. These deposits might be worked out along

Deposit No. 6 on the John Bryan Land.



Ore outcrops in abandoned roadway southeast of Bloomfield. John W. Craven land; 40 rods from B. & B. branch of Monon Railroad.

with the larger deposits. Sample No. 8, selected specimens from a number of concretions from this deposit.

Deposit No. 8.—In the southeast ¼ of section 4 and the northeast ¼ of section 9, south of Solsberry, are found large blocks of siliceous iron ore, also some outcropping ledges. This ore has been greatly overestimated. It was recently estimated by a prospector as containing 500,000 tons of workable ore. The ore is due to the filling and replacing of the sandstone and it is doubtful if this line of deposit will prove to be of any practical value.

Analyses.—The samples taken for analyses in Greene County were necessarily of higher iron content than the deposits would run in mining. Many of the excavations were not made through the entire thickness of the ore, and in other places the samples were taken from the leached outcropping faces. The analyses are given in the table and are numbered to correspond to the numbers given under the deposits.

ANALYSIS—GREENE COUNTY—IRON ORES.

Material Dried at 135° C.

Mark.	SiO_2	Fe.	Al_2O_3	CaO	P	S	Mn.
1	25.74	43.48	3.94	0.20	.198	.07	.102
2	....	51.51	....	....	....	....	....
3	10.14	48.73	10.59	1.30	.702	.04	0.519
4	8.15	51.35	9.18	.60	.759	.80	0.279
5	16.87	42.01	5.68	.25	.455	.07	0.079
6	4.60	36.61	6.10	2.80	.479	.27	0.615
7	....	42.52	....	....	....	....	....
8	....	49.81	....	....	....	....	....
9	....	54.00	....	....	....	....	....
10	....	40.95	....	....	....	....	....
11	17.00	39.20	2.00	....	....	....	....
12	....	38.21	2.50	.12	....	....	....

MARTIN COUNTY.

By J. W. Beede and C. W. Shannon.

The work of exploiting the Martin County iron ore field was accomplished during the fall of 1905, and the winter and spring of 1906, for the Chicago, Indianapolis & Evansville Railroad Company, who desired to know the resources of the county and to determine as to the feasibility and advisability of opening up ore mines in that section. Much work was done in locating the outcrops of ore deposits, cutting of vertical faces and driving entries into the deposits, and in diamond core drilling to determine the extent of the ore in the hills.

Plate XXVI.

Deposit No. 7. Accumulation of kidney ore along sides of ravine.

Deposit No. 7. Ledge of replaced sandstone with kidney ore overlying.

This company deserves great credit for generously placing all the information, gained at an expense of thousands of dollars, at our disposal without compensation or reservation. We desire to express our gratitude to them for this generous act.

Location and Geology.—Martin County comprises an oblong strip of territory in the southwestern part of the State. Its maximum length from north to south is 28 miles and the greatest width is 13 miles. It is bounded on the north by Greene, on the east by Lawrence and Orange, on the south by Dubois, and on the west by Daviess County.

The surface rocks of the county are of three separate geological epochs, viz.: the Coal Measures and Mansfield sandstone of the Carboniferous and the Huron limestones and sandstones of the Lower Carboniferous periods. The Mansfield sandstone covers at least two-thirds of the county, the Coal Measures proper being found only in the southeastern corner and in irregular isolated patches on the tops of the higher hills and ridges of the central portion. The Huron group is chiefly in the eastern third; it is, however, exposed along the streams north of the center and along White River to a point west of Shoals.

The scenery is rugged and picturesque and cannot be excelled in the State. The surface is a thoroughly dissected plateau. The hills rise from one hundred and fifty to three hundred feet or more in height, and in many cases have almost precipitous sides.

The East Fork of White River meanders in a southwestern course through the county and with its main tributaries, Boggs and Indian Creeks, on the north, and Beaver Creek and Lost River on the south, constitutes the drainage system of the county, with the exception of the extreme northern end, which is drained by Furse Creek into the West Fork of White River. The East Fork and its tributaries have been the chief agents in producing the striking topographical features. The work of the streams in this area was never arrested by the invasion of an ice sheet, therefore the county has all the characteristic ruggedness of unglaciated regions. South and east of the river the county is more rugged than that portion to the north of the river, since the Mansfield sandstone is more massive and probably thicker.

The mineral resources of the county consist of coal, iron, limestone and sandstone and shale. The coal is thin-bedded, but is of a fairly good grade, but on account of the difficulty of mining it is of little importance except for local use. The limestone and sandstone are not of sufficient value as building stone to expect any extensive use to be made of them for that purpose. There are extensive beds of shale, but they have not been developed.

The Iron Ores.—The iron ore area of Martin County ranks first in the State. In the shales of the coal measures and near the base of the sandstone overlying the Huron limestone are found considrable deposits of iron ore. The occurrence of iron in the coal measures is in many respects like that of coal. Like coal it is found in seams varying in thickness from the fraction of an inch to forty or fifty feet or even more. Like coal the thicker seams are apt to be less pure from the presence of clay, etc. The veins of greatest richness are seldom more than three or four feet in thickness. The ore deposits are also similar to coal in that they are often repeated in the same section and that they are usually underlain by more or less clay or shale.

All the classes of ore mentioned in the introduction on the Indiana ore fields are found in this county in a greater or less degree. The first classes in the order of their abundance are carbonates, hematites, limestone and sandstone ore. The kidney or concretionary ore is very plentiful, but it belongs chiefly to the carbonate

Plate XXVII.

Looking north from the Pinnacle, Shoals, Ind. Showing the White River Valley and the iron-bearing hills in the background.

class, the inner part being carbonate, with the thin outer coating of iron oxide.

Prospecting.—As stated above the greater part of the developments that have been made in the Martin County ore field were recently made for the Chicago, Indianapolis & Evansville Railroad.

The ore map accompanying this report shows the area over which the most careful investigation was made. It is not to be understood from the map that the entire area under the ore markings is covered by workable ore deposits. The area includes the chief deposits which in most cases are noted on the map by special markings, and it also includes the area over which more or less iron ore is scattered, showing the possibility of a deposit nearby. The map then is more of a guide to lead to the finding of deposits than a real index of known deposits. The existence of deposits outside of the area mapped is known, i. e., deposits of considerable importance to the south of Lost River, and also to the west and north of White River. In this latter locality, however, no extensive deposits are known, but the surface in many places shows very good indications of iron and developments may show the presence of some workable deposits. The area mapped is the heart of the ore field, but the time at our disposal did not permit the mapping of the other localities. The iron scattered along the streams and hillsides may be traced almost continuously from the outcrop of one deposit to that of another, and while this is of great assistance in finding workable lenses it cannot be relied upon entirely, since in some cases where iron is profusely scattered over the ground, even at the level of the line of deposits, no deposits are found. The origin of the ore and the manner of its deposition have a great deal to do with the uniformity and continuity of the deposits.

Core Drilling.—Several drill holes were put down to depths varying from 50 feet to more than 200 feet. These holes were drilled back on the ridges at various distances from the ore outcrops, in some cases penetrating the ore deposits and in other cases showing the absence of ore. From the records of the drill holes and the information gained by facing the outcrops and driving entries we were enabled to approximately estimate the ore tonnage of the several deposits. Samples for analysis were taken from the cores and then the remainder of the core in the part of the hole where the mineral occurred was securely boxed in core boxes made to carry from one to four sections from four to ten feet in length. In each box was placed a description as shown below, so that if samples for analysis were again taken they could be properly located, or in order that persons interested might compare the "log," or diagram, of the boring with the core and determine the character of the strata and the regularity of the formations as they occurred in the various localities. The logs of the borings also accompany this report, and from them it will be seen that the formations are very irregular and broken and that which was found in one hole might be missing altogether in a boring only a little distance away. On this account it was impossible to correlate the logs of the borings over any large area.

Blank to be filled and placed in core drill boxes with each of the sections of ore or other core to be saved:

SAMPLE OF CORES.

Taken at depth of ....feet on ....,1906.
From land of ....
In ....
Of Section ...., Town ...., Range..........
County of ....State of Indiana.
Prospect Hole ...., drilled by ....
Shipped ...., 1906.
...., Supt.

Elevations.—The elevations of the openings and prospect holes were determined by a corps of engineers, employed especially to do that work. As a starting point in the determination of these elevations the U. S. Coast and Geodetic Survey bench mark at Shoals was the base. From the bench marks of these engineers the minor elevations in various parts of the field were made by barometer readings.

When the elevation of the base or top of an outcrop was known and also the surface elevation at the point where drillings were made the dip of the strata could readily be estimated and the probable depth to which the boring must be made could also be ascertained.

Many of these elevations and bench marks are so marked that they may may be used in the future for years. Hence the list of the more important points is given below. These points are located in such a way that they can be easily found and will be of value to persons doing geological research or to mineral investigators or persons wishing to determine the elevation of surrounding points for other purposes.

List of Elevations and Bench Marks in Martin County, Indiana.

Government B. M. on window sill of court house, Shoals, Ind., 523 feet.

Southeast corner river bridge. Ele. 482.71.

Iron step corner of old News office. Ele. 504.40.

In Halbert township, north and east of Shoals: Shirley Ore Opening. Ele. 623.51, 107 feet southwest of peg on gum tree; B. M. 624.81, nail in root of same tree.

Top of ridge on east Clifton line. Ele. 732.05. Cherry tree 15 feet southeast of peg; B. M. 731.61, nail in root of same tree.

Iron bridge at Melvins-Shoals-Willow Valley Pike; B. M. 482.13, southwest corner bridge.

No. 15. Ele. 728.58, on oak tree 35 feet northeast of hole; B. M. 729.05, nail in root of same tree.

Ritter Spring. Ele. 673.46, cross on stone, ele. marked on fence.

Base of Mundey Opening No. 15. Ele. 650.56, marked on stone.

First bench from top of Mundey Hill. Ele. 686.45, marked on stump.

Top of Mundey Hill. Ele. 720.87, marked on stump 40 feet north; B. M. 718.04, nail in root of same stump.

Top of Thompson Hill. Ele. 721.99, marked on hickory tree 12 feet south; B. M. 721.47, nail in root of same tree.

Thompson Opening No. 14. Ele. 674.78, marked on Poplar tree 50 feet southwest opening; B. M. 681.56, nail in root of same tree.

Radcliffe Schoolhouse. Ele. 683.32, marked on southeast corner schoolhouse; B. M. 682.04, marked on stone southeast corner schoolhouse.

McKnight's barn. Ele. 731.21, marked on barn.

Tow's mail box. Ele. 693.08, marked on post.

In Columbia Township, south of Shoals:

Boring No. 1A. Ele. 773.02, marked on Persimmon tree 110 feet east; B. M. 774.05, nail in root of same tree.

Boring No. 1. Ele. 674.62, marked on stump 75 feet southwest; B. M. 673.41, nail in root of same stump.

Boring No. 2. Ele. 712.71, marked on oak tree 50 feet south of hole; B. M. 708.30, nail in root of same tree.

Boring No. 3. Ele. 723.38, marked on ash tree 75 feet northeast; B. M. 722.02, nail in root of same tree.

Boring No. 4. Ele. 612.09, marked on hickory tree 50 feet west; B. M. 587.94, oak tree 200 feet south of hole.

Boring No. 5. Ele. 592.68, marked on oak tree 50 feet southeast; B. M. 587.94, nail in root of same tree.

Base Horner Opening No. 6. Ele. 547.25, marked on post at opening; B. M. 587.94, oak tree 150 feet west of opening.

Boring No. 8. Ele. 662.74, marked on walnut tree 30 feet west.

Gammon Point, above opening No. 11. Ele. 682.34, marked on old stump 25 feet north; B. M. 682.89, nail in root of same stump.

Boring No. 6. Ele. 662.24, marked on old snag 170 feet northeast of point; B. M. 659.94, nail in root of same snag.

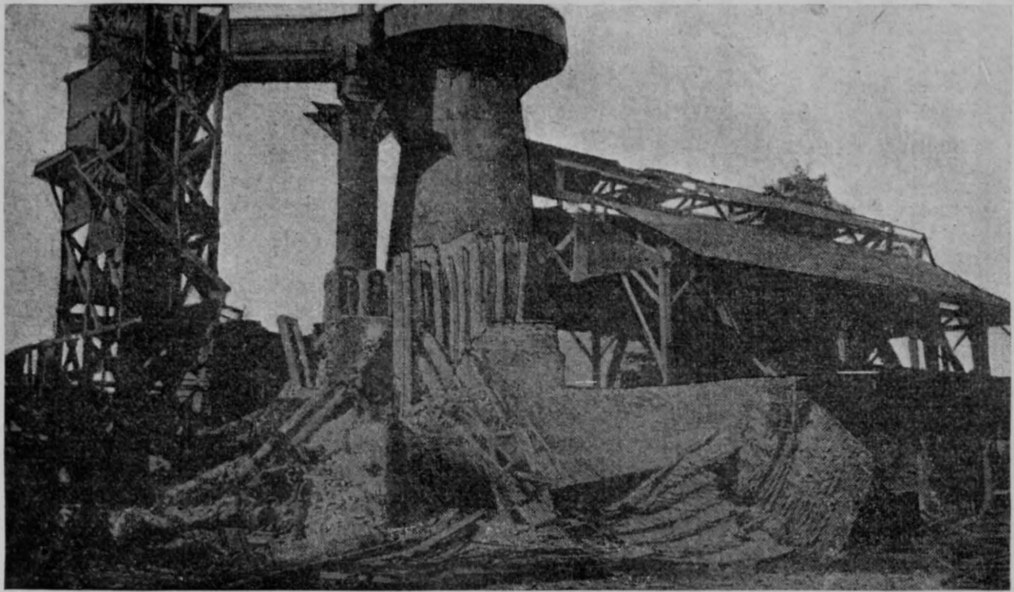
Albright Point. Ele. 664.97, marked on stump.

Boring No. 7. Ele. 600.90, marked on stump 12 feet west; B. M. 601.66, nail in root of same stump.

Martin County Blast Furnace.—About 1870 people became interested in the iron ores of the county and they employed Robert Dale Owen, geologist, to investigate and report on the iron ore deposits. This led to the organization of an ore mining and smelting company. It met with various difficulties, and during its existence was operated under a half dozen names, but during the most interesting and successful days it was known as the "Nelson Furnace Company." When working at its best, about 1873, several hundred men were employed, many of them among the hills mining the ore and others making coke. The furnace was located a little more than half a mile east of Shoals, and the thriving little town that sprang up around the furnace was incorporated under the name of Ironton, but when the furnace ceased operation the town rapidly declined and all that remains today, as can be seen from the B. & O. S. W. Railroad, are heaps of cinder about the location of the old furnace and on the opposite side houses empty and deserted. The product of this furnace was called "the American Scotch Pig," and with the "Hanging Rock" made at Ironton, Ohio, was regarded as the nearest American approach to the popular "Scotch Iron."

The furnace was operated under discouraging conditions. The railroad, then under the management of the old O. & M., was oppressive in the excessive freight rates charged. The result of the railroad's policy was failure of the iron company. The company found it necessary to reduce expenses and in so doing a $2,500 superintendent was discharged and replaced with a $50-a-month-man, who was inexperienced, and during the first week after he took charge he let the furnace chill and there was an accumulation of gases which caused an explosion which entirely destroyed the plant.

Plate XXVIII.



Martin County Blast Furnace after it ceased operation.

Some Missouri Iron Mountain ore was mixed with the siliceous native ore and by this process a neutral iron of excellent quality was produced. Not only was the iron put on the market in former years, but in recent years J. B. Loyd, secretary of the old iron company, shipped several carloads of the ore left lying about the old furnace, to the Globe Iron Company at Jackson, Ohio. Mr. Loyd has a letter which Mr. Crandall, president of the Ohio company, wrote to him concerning the Martin County ore. "The ore worked very satisfactorily. It melted easily and made the best class of high silicon iron and we are very much pleased with it all the way through. The ore seemed to vary in richness, but on the whole the yield was very fair." This letter indicates the desirability of the ore from a commercial point of view.

When the furnace ceased operation things were just in preparation for extensive mining in Martin and adjoining counties. New deposits had been opened, and more men engaged to take out the ore, but with the failure all the work declined and the interest was not again revived until within the last few years, during which time considerable money has been expended in investigation and development.

The following from the report of Prof. E. T. Cox, on the iron ores of Martin County, is here copied for comparison of analysis, location of deposits, value and uses of the ore, and the origin of deposits.

"Near the junction of the millstone grit, with the lower carboniferous limestone, there is more or less iron ore throughout the county. Generally, it is a siliceous hydrated oxide, which lies in pockets, or local beds, often of great extent; but there are some localities where an earthy carbonate of iron is found in seams that vary from a few inches to six feet in thickness, though, usually, where attaining the greatest thickness, it is mixed with more or less silex. No effort has been made to properly open either the iron ore beds, or seams of coal in Martin County; consequently, I found it difficult to pronounce, with any degree of certainty, on the true commercial value of the minerals, seen under so great a disadvantage. To pick into a seam of ore or coal, through the superincumbent earth and rock with a common geological hammer, seldom enables one to see the stratum, in so favorable a light, as where a clean vertical face is shown, by proper excavation.

"On Mr. Stevens' land, section 1, township 3, range 3, near the top of a hill, by the base of which runs the Ohio and Mississippi Railroad, there is a deposit of iron ore fully thirty feet thick and

Ruins of the Martin County Blast Furnace as it appears today.

Siliceous Iron-Ore outcrop along roadside in Sampson's Hollow, south of Shoals. This material has been used for road metal.

half an acre in area, which contains a large per cent. of metal, but is also quite siliceous, it has a reddish brown color and contains bands of a gray steel color. The ore lies in regular stratified blocks, as though the conglomerate sandstone had been metamorphosed, or changed by displacement, into an ore of iron.

"Chalybeate waters may have been chiefly instrumental in bringing about the conversion of the sandstone to ore, as springs of this water are quite common at the base of the millstone grit.

"Specimens of this ore were taken for analysis, and after crushing equal portions from three varieties, and then reducing them to an impalpable powder, a weighed portion of the mixed ores gave:

No. 1.

Insoluble silicates	27.00
Ferric oxide	66.40
Alumina	1.10
Phosphoric acid	trace
Sulphur	trace
Lime	trace

The yield of metal is equal to 44.48 per cent.

Similar deposits of siliceous ore are seen on sections 15 and 16, township 3, range 3.

Two varieties, which represent the larger portion of the ore bed, were taken for analysis, and gave the following:

No. 2, limonite; color, reddish brown; containing small cavities filled with decomposed ore and clay; running through the mass are streaks of steel gray ore, with glistening specks of quartz:

No. 2.

Moisture dried at 212° F.	1.24
Ignited to bright red heat, lost	6.56
Silica and silicic acid	28.60
Ferric oxide	54.45
Alumina	7.20
Phosphoric acid	trace
Sulphur	trace
Lime, magnesia and loss	1.95
	100.00

No. 3.

Color: Dark brown, mottled with pink.

Moisture. dried at 212° F.	1.00
Ignited to bright red heat, lost	8.00
Insoluble silicates	36.80
Ferric oxide	49.95
Alumina	2.12

The ferric oxide equals 34.96 per cent. of metal. The roasted ore will give about 38.41 per cent. of metal.

No. 4 contains too much silica to be worked with advantage in the blast furnace.

Nos. 1, 2 and 3, though containing a large amount of silica, are quite rich in iron and alumina and it is my opinion that they will work very well in the blast furnace, especially when mixed with a small proportion of hematite ore. The metal will be hard and well adapted for rails.

On sections 14 and 32, resting on the shale, forming the roof of the coal in Munson's Ridge, is a bed of siliceous iron ore two feet thick.

No. 5.

Moisture, dried at 212° F.	4.00
Ignited to bright red heat, lost	9.11
Insoluble silica and silicic acid	32.35
Ferric oxide	53.00
Lime, magnesia, and loss	1.54
	100.00

The ferric oxide equals 37.10 per cent. of metal.

If roasted, this ore will yield over 41 per cent. of iron, but contains too much silica to be worked alone.

There is a four-inch layer of bituminous ironstone that is very rich in iron, as may be seen by the partial analysis here given:

No. 6.

Moisture, dried at 212° F.	1.00
Ignited to bright red heat, lost	28.00
Insoluble silicates	7.00
Ferric oxide	60.50
Sulphur	trace
Phosphorus	trace

The ferric oxide is equal to 42.35 per cent. of iron.

If roasted, this ore will yield about 60 per cent. of metal. A portion of the 28.00 per cent. expelled by ignition is bitumen. In some respects it resembles the celebrated black-band ore-Mushet-stone of Airdrie, Scotland.

In the bluish gray shales overlying the top coal in Sampson's Hill, there are a number of irregular bands of clay iron ore; a similar ore is seen in the shales which overlie the lower coal seam. At many places where the coal has been opened, and where exposed in washes, in the hillsides, a considerable quantity was also seen in the road leading to Baker's, south of Sampson's hill, and at Willow Valley, on the Ohio and Mississippi Railroad. The subjoined analysis shows it to be a good ore:

No. 7.

Moisture, dried at 212° F.	1.15
Ignited to bright red heat, lost	24.05
Insoluble silicates	8.00
Ferric oxide, with some alumina	60.00
Phosphoric acid, undetermined.	
Sulphur, undetermined.	
Lime, magnesia and loss	6.80
	100.00

The ferric oxide is equal to 42 per cent. of metal, and this ore, after roasting, will yield 56 per cent.

On sections 9 and 10, township 4, range 3, lying about thirty feet above the lower carboniferous limestone, there is a bed of ironstone, which is, where I saw it exposed, four feet thick; samples from four parts of the bed were taken for analysis, and the result is here given:

No. 8. Lower stratum: greenish gray ore. About half a pound of the ore was crushed in an iron mortar, and the small quantity required for analysis was taken therefrom and reduced to an impalable powder in an agate mortar, by which means a good average was secured:

Moisture, dried at 212° F.	1.40
Ignited to bright red heat, lost	22.80
Insoluble silicates	13.00
Ferric oxide (equal to 38.92 per cent. metal)	55.60
Carbonate of lime and magnesia	5.60
Sulphur	.90
Phosphoric acid, undetermined.	
	99.30

No. 9.—Lower portion of the middle member.

Moisture, dried at 212° F.	3.00
Ignited to bright red, lost	10.50
Insoluble silicates	23.00
Ferric oxide (equal to 41.75 per cent. of metal)	59.65
Alumina	2.70
Phosphoric acid	trace
Lime, magnesia and loss	1.15

No. 10.—Upper portion of middle part.

Moisture, dried at 212° F.	3.00
Ignited to bright red heat, lost	8.00
Insoluble silicates	37.75
Ferric oxide (equal 33.63 per cent. metal)	48.05
Alumina	1.15
Phosphoric acid	trace
Lime, magnesia, and loss	2.05
	100.00

No. 11.—Upper stratum, four inches thick at the crop.

Moisture, dried at 212° F.	.30
Ignited to bright red heat, lost	28.50
Insoluble silicates	8.50
Ferric oxide (equal to 37.52 per cent. metal)	53.60
Phosphoric acid	trace
Sulphuric acid	trace
Lime, magnesia and loss	9.10
	100.00

"From the above analyses the average yield of iron from the ores of this bed will be about 37.95 per cent. and the average per cent. if silicates about 20.56. Though the silica is pretty large, still I am of the opinion that the ore may be worked in the blast furnace, alone, but mixed with the hematite ores of Missouri, will undoubtedly yield a metal of excellent quality.

"As already stated, the seams and deposits of iron ore are large and numerous, though, for the most part, siliceous; there are some stratified ores comparatively free from silica, and I am of the opinion that when thorough search has been made, by digging into the shales lying between the millstone grit and lower carboniferous limestone, that the six-foot seam, previously referred to as occurring on section 9, township 3, range 3, will be found, in many places, where it may prove to be of still better quality.

The average yield of iron, from the ores analyzed, is nearly 38 per cent., which is sufficient to be remunerative, as they can be had convenient to coal suited for smelting them, and may be mined at little expense. At all events, should it not be deemed advisable to smelt these ores by themselves; rich hematite ores that will make an admirable mixture may readily be had from Missouri, over the Ohio and Mississippi Railroad. Indeed, Shoals would prove an admirable location for a blast furnace, even though all the ore had to come from Missouri. It is situated on the East Fork of White River, is now the county seat and quite a flourishing manufacturing town, containing mills for cutting staves and headings, spoke, hub, and axe-handle factories, saw mills, planing mills and potteries."

The Iron Ore Deposits.

The iron ore deposits of Martin County lie in two main districts, one south of Shoals, the other to the northeast. It has been the general impression that the region to the south is the chief ore field of the county. Such would appear to be true in traveling over the county, since there are numerous outcrops and the fragments of the ore, or "floaters," are distributed over a wide area. The outcrops in the northeastern field are not so numerous, but are on the average much thicker and have greater persistency through the hills.

The chief deposits of each field will be taken up and briefly described. The order of numbering is that in which the samples for analysis were taken from the deposits at the first, and these numbers will be used throughout in referring to the deposits and the table of analysis.

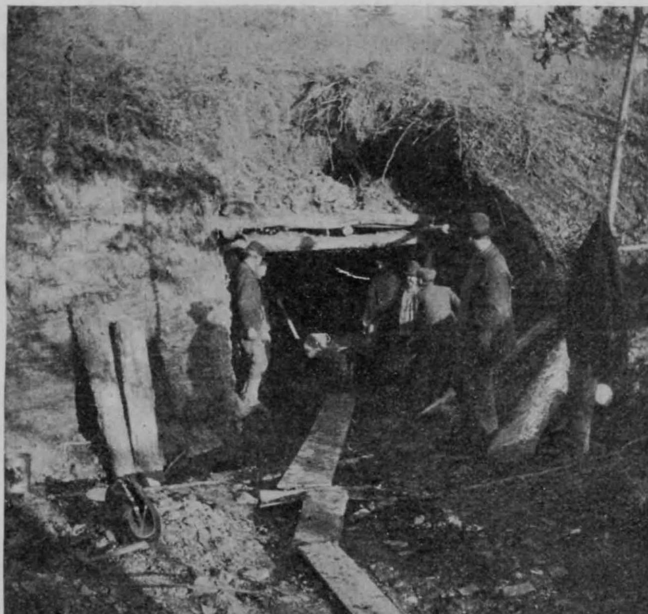
(a) The Southern Field.

The area south of Shoals contains many small ore bodies, located largely in the vicinity of "Coal Hollow." There are two lines of deposits, with an average difference in elevation of about 40 feet. The deposits are "local pockets," and are not continuous in workable thickness. The deposits will be spoken of as the upper and lower ore.

Opening No. 4.—Located on the J. A. Cook land, west side of S. W. 1/4, S. E. 1/4, section 6, township 2 N., range 3 W. Elevation 642 feet, about 90 feet above drainage. This deposit is on the point of a hill, with three sides exposed. It is a high grade carbonate ore oxidized on the surface. There is a thin covering of clay over this, however, and clay seems occasionally in it. This ore is from 4 to 6 feet thick and covers about 60,000 square feet and contains 15,000 tons. This will probably be best secured by scramming. It can be put on the cars at a low cost. Three samples from near the surface gave the following average analysis.

Water	10.50
Silicon	16.90
Metallic iron	39.63
Aluminum	4.70
Ferric oxide	56.62
Lime (CaO)	.85
Phosphorus	.65
Manganese	1.02

Plate XXX.

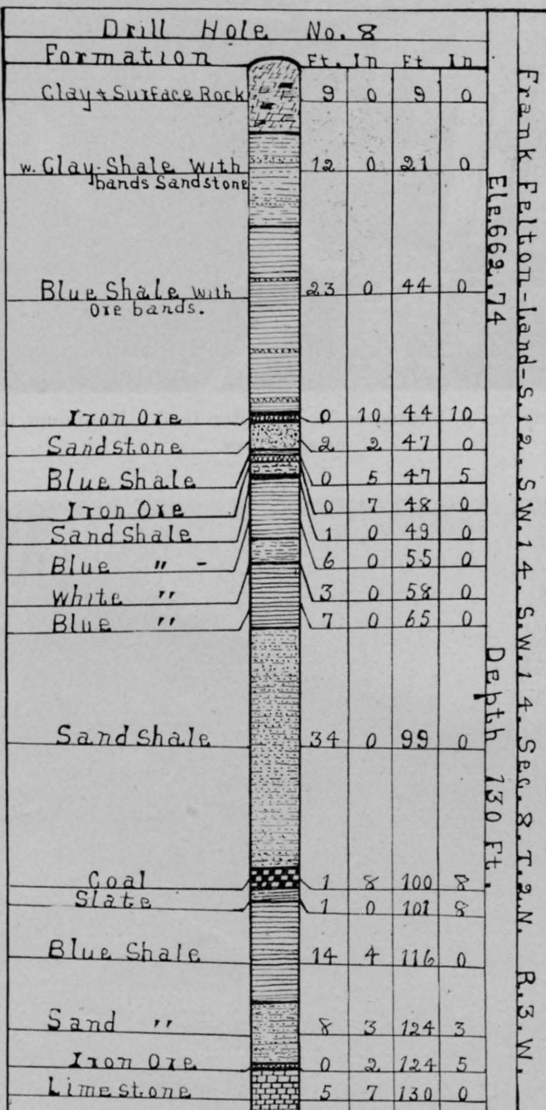


Opening No. 5, located on F. M. Felton land. Maximum thickness, six feet.

Opening No. 6. Opening ore outcrop in order to cut a vertical face.

About 50 feet below the above deposit is a thin deposit of the lower ore, and along the ridge for some distance to the east a highly siliceous ore two to three feet thick outcrops in several places.

Opening No. 5.—Located on F. M. Felton's land, center S. W. ¼, S. W. ¼, Sec. 8, T. 2, R. 3 W. Elevation 642 feet, 10 feet above drainage. The ore is brown on face, but is blue carbonate



within, some of it containing so much bituminous matter that it is almost black.

This ore bed has a frontage of 300 feet and a maximum thickness of 6 feet and in prospect hole No. 8, 320 feet southeast of the opening, the ore was shown to be 10 inches in thickness. Considering the backward extension at 200 feet gives this bed an average thickness of 4 feet of available ore, with a tonnage of 20,000 tons. The average analysis is as follows:

Water	9.20
Silicon	19.40
Metallic iron	36.95
Aluminum	5.84
Ferric oxide	51.51
Lime	3.46
Phosphorus	.52
Sulphur	.240
Manganese	.267

This ore may be easily mined and for loading in the cars would require a slight hoist. A workable vein of coal lies 15 feet above this ore.

Opening No. 6.—This deposit is located on the Sarah Horner land, southwest corner N. W. ¼, S. W. ¼, Sec. 17, T. 2 N., R. 3 W. The deposit is of the lower ore and lies about 40 feet above drainage. The elevation at the base of the ore is 547.25 feet. The main body of the ore lies directly on the limestone and has replaced and filled the limestone to a depth of about two feet. The ore has a maximum thickness of 12 feet, with an average workable thickness of six feet or more. The frontage is at least 500 feet and it extends backward into the hill 225 feet to prospect hole No. 5, where the drill penetrated two feet of it, mostly of the limestone variety. This hole, at the surface, has an elevation of 592.68 feet. More or less broken, siliceous and shaly ore was passed through, aggregating a thickness of from four to five feet, but on account of wide parting and the low grade of the ore it is not of workable value.

Along the outcrop of the lower deposit a vertical face was cut more than 75 feet in length and backward to the maximum thickness, and then from this vertical face an entry was driven for about 15 feet, showing the ore to be of the same general character throughout. It is of a reddish brown color and becomes somewhat mottled when exposed to the weather. The deposit would yield at least 56,000 tons of ore. Several analyses were made of this ore

Plate XXXI.

Deposit No. 6. Showing dip of deposit and entry driven backward from face.

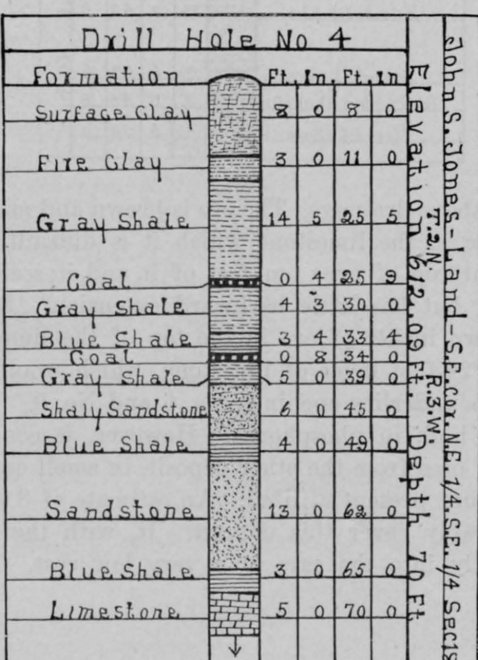
Deposit No. 6. Maximum thickness of 12 feet on vertical face.

and are given in the table. The average analysis of which is as follows:

Water	9.20
Silicon	20.85
Metallic iron	39.74
Aluminum	7.67
Ferric oxide	56.75
Lime (CaO)	6.81
Phosphorus (P)	.751
Sulphur	.081
Manganese	.880

The cost of removing this ore would be very low. At the maximum thickness there would be very little stripping. And farther back it has a sandstone roof from under which it could be mined. There is ample room for trackage below, and the ore can be dumped directly into cars from above.

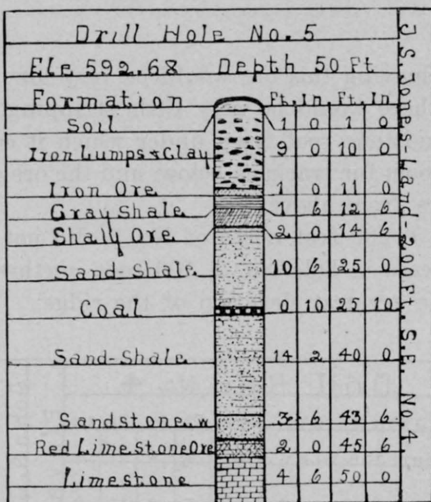
Drill hole No. 4, 200 feet north of No. 5, did not strike the ore, as was also the case in hole No. 2, 100 rods northwest of opening No. 6, and at the greatest elevation of the ridge.



Opening No. 7.—H. A. Stephens' land, N. E. ¼, N. E. ¼, N. E. ¼, Sec. 17, T. 2 N., R. 3 W. This is a small deposit in the upper ore, elevation 640.62 feet. The thickness at the face is four feet and has a frontage of 250 feet, but does not extend but a short distance into the hill. Drill hole No. 1, 225 feet to the northeast, shows only three or four thin bands of the ore as parting in two feet of shale.

The sample analyzed shows an iron content of 38.82.

Opening No. 8.—On the Sarah Horner land, northeast corner S. W. ¼, S. W. ¼, Sec. 17, T. 2, R. 3 W. Elevation 545 feet.



About 40 feet above drainage. The ore is brown and massive. There is a bed of ore in the limestone which it is difficult to estimate. There is an outcrop of over ten feet of it and it seems to have a good frontage, but has little backward extension. Boring No. 7 showed only two inches of ore in the top of the limestone. It is located in the 24-foot layer of limestone, which would be used as flux and which underlies openings No. 6 and No. 9. It is high in iron, but also high in phosphorus. However, it could be mixed with the sandy ores from the other deposit, in small quantities, and the entire amount present utilized. An estimate of 8,000 or 10,000 tons will probably cover this deposit. It, with the flux, can be dumped directly into the cars at a very low cost. The average analysis is:

J.S. Jones-Land-N.W. Cor. N.E. 1/4. S.E. 1/4. Sec. 18. T. 2. N. R. 3. W.-

Drill Hole No. 2

Ele. 712.71 Depth 210 Ft

Formation	Ft	In	Ft	In
Surface Clay	3	0	3	0
Sandstone	18	0	21	0
Blue Shale	12	0	33	0
Coal	0	8	33	8
Clay Shale	3	4	37	0
Blue "	11	0	48	0
Sandstone	9	0	57	0
Blue Shale	8	0	65	0
Sandstone	5	0	70	0
Blue Shale	22	0	92	0
Sandstone	1	0	93	

No. 2 - - - Continued- - - - - -

Blue Shale	44	6	137	6
Shaly Coal	1	6	139	0
Fire Clay	6	0	145	0
Soft Shale	4	0	149	0
Ore with Shale	2	0	151	0
Blue "	1	7	152	7
Coal	0	8	153	3
Sand-Shale	26	9	180	0
Sandstone	21	0	201	0
Sand Shale	9	0	210	0

Drill Hole No: 1

Formation.	Ft.	In.	Ft.	In.
Surface Clay	13	0	13	0
Gray-Sandstone	8	0	21	0
Black Shale	13	0	34	0
Ore & Shale	2	0	36	0
Black Shale with-Ore-lumps	39	0	75	0
Black Shale	22	0	97	0
Sandstone. White	23	6	12.0	6
Hard-band-Ore	0	4	120	10
Black Shale	0	8	121	6
Limestone	24	6	146	0
Green Lime-Shale	5	0	151	0

Elevation 674.62. Ft.

Depth 151 Ft.

H. A. Stephen - Farm - N.E. Cor. N.E. 1/4 N.E. 1/4. Sec. 18. T. 2 N. R. 3 W.

C. W. Shannon.

Drill Hole No. 3.

J.L. Gay—Land—N.E. Cor. N.E. 1/4. S.W. 1/4. Sec. 18. T. 2 N. R. 3. W.

Ele 723.38 Depth 200

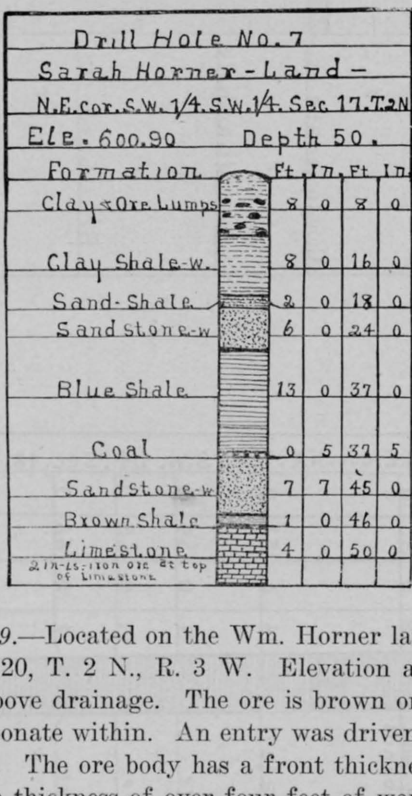
Formation	Ft.	In	Ft	In
Clay & Surface Rock	11	0	11	0
Soft Shale—Gray	5	0	16	0
Sand-Shale—With Ore bands	19	0	35	0
Blue Shale	16	0	51	0
Gray "	3	0	54	0
Blue "	11	0	65	0
Iron Ore	1	0	66	0
Blue Shale	18	10	84	10
Coal	1	6	86	4
Fire Clay	1	8	88	0
Sand Shale	7	0	95	0
China Clay—W—	1	0	96	0
Red Sandstone—With Ore bands	7	0	103	0

No. 3 — — — Continued — — —

Formation	Ft.	In	Ft	In
Red Shale	2	0	105	0
Sand "	2	0	107	0
Blue "	30	0	137	0
Conglomerate—Ls—	1	0	138	0
Soft Blue Shale	21	0	159	0
Blue Sand "	31	0	190	0
Sandstone	0	6	190	6
Limestone Ore	0	6	191	0
Blue Shale	0	7	191	7
White Limestone	2	0	193	7
Limestone With Crevices Partly Replaced with Iron	4	11	198	6
Blue Limestone	1	6	200	0

Water	6.50
Silicon	11.20
Metallic iron	51.52
Alumina	.80
Lime (CaO)	2.91
Phosphorus	1.00
Manganese	3.96

The origin of this ore is due in part to the filling of cavities in the limestone, but chiefly to replacement.



Opening No. 9.—Located on the Wm. Horner land, in N. W. 1/4, N. W. 1/4, Sec. 20, T. 2 N., R. 3 W. Elevation at base 560 feet; about 50 feet above drainage. The ore is brown on the outer part, but largely carbonate within. An entry was driven into the deposit for several feet. The ore body has a front thickness of seven feet, with an average thickness of over four feet of workable ore as far as investigated. The exact extent of the deposit into the hill was not determined by drilling, but 200 feet is a conservative estimate. Its lateral extent is at least 800 feet, and along this line several small openings were made, showing the ore to be of the same quality. The deposit contains 53,000 tons of ore easily accessible. About forty feet above this deposit is another with a maximum thickness of four feet, and this would greatly increase the tonnage at this place. The average analysis is as follows:

Water	8.50
Silica	22.47
Metallic iron	41.63
Aluminum	7.11
Ferric oxide	59.47
Lime	1.40
Sulphur	.754
Phosphorus	.822
Manganese	.192

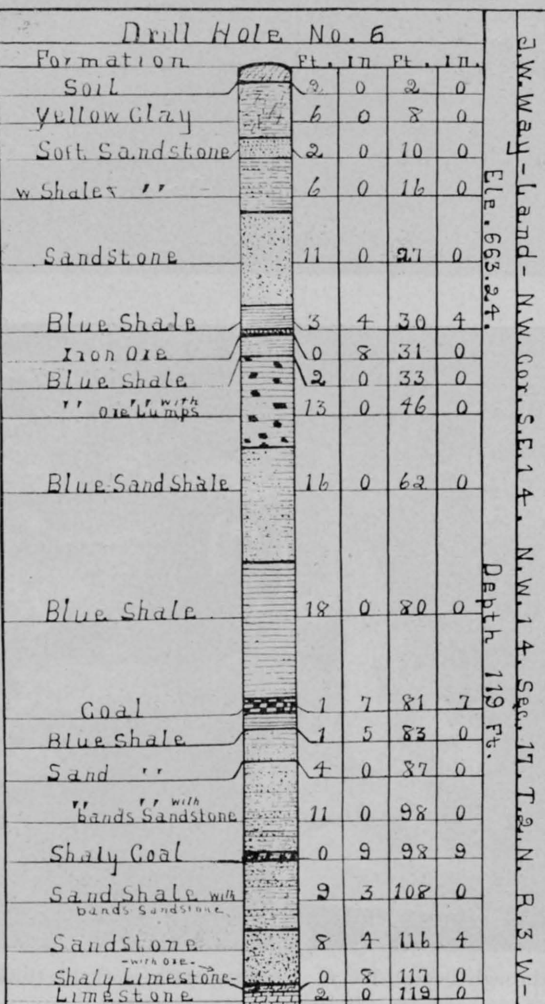


Plate XXXII.

Cut through Deposit No. 6. Showing entire workable thickness of ore. Bottom of cut is limestone.

The iron content of these analyses and the average analysis should be increasing, because in both samples two feet of slaty, iron-bearing shale at the base was included, which reduces the iron content of the thickness given above and increases all the impurities accordingly.

Opening No. 10.—Located on the Phillip Gammon land, north side N. W. 1/4, N. W. 1/4, Sec. 17, T. 2 N., R. 3 W. Elevation 645 feet. This deposit was opened in the roadside just south and below the Gammon coal mine. The ore is banded and concretionary and is intermixed with clay. The deposit is about five feet in thickness and borders the edge of the hills for considerable distance. The tonnage would be hard to estimate, but a large amount of ore could be taken out at a small cost by hand mining.

Opening No. 11.—Phillip Gammon land, central S. E. 1/4, S. W. 1/4, Sec. 8, T. 2 N., R. 3 W. Elevation is 645 feet. This opening is 40 rods N. W. of No. 10, and is similar to it in every respect. No. 11 is 60 rods southeast of opening No. 5. Boring No. 8 is on a line between the two openings.

These openings lie just above drainage level.

Opening No. 12.—On the Stewart farm, S. E. 1/4, S. E. 1/4, Sec. 5, T. 2 N., R. 3 W. Elevation 625 feet; 10 feet above drainage. This deposit has a frontage of 400 feet and extends back from the face at least 250 feet and has a maximum thickness of 9 feet and contains 75,000 tons of ore. The ore is blue carbonate and is a massive conglomerate, containing concretions of very compact carbonate.

There are at least two accessory lenses within 200 yards of the above deposit, which will increase this tonnage considerably.

The average analysis of the main deposit is as follows:

Silica	23.52
Iron (Met.)	31.82
Aluminum	4.94
Ferric oxide	45.46
Lime	2.80
Phosphorus	.494
Sulphur	.476

This ore can be easily mined and put on cars at a small cost.

Opening No. 13.—On Johnson's land, S. W. 1/4, N. E. 1/4, Sec. 7, T. 2 N., R. 3 W. Elevation 635 feet and it is about 40 feet above drainage. The ore is brown on the surface, but blue within. The deposit has a front of upwards of 800 feet, with an average thickness of four feet or more. It apparently extends into the hill 200 feet or more and contains at least 35,000 tons. It has a sandstone roof. No recent facing was made at this deposit, hence the sample from the face for analysis was somewhat leached. The analysis shows 46.45 per cent. metallic iron, and back in the carbonate ore it will run about 40 per cent. It can be removed without difficulty.

Opening No. 17.—On the Felton land, 60 rods north of opening No. 5, and is in the same line of deposits. The quality of the ore is lower than No. 5, but the sample taken shows an iron content of 33.94 per cent. Shale partings break up the deposits.

Opening No. 18.—Davisson land, S. E. 1/4, Sec. 19, T. 2 N., R. 3 W. This opening shows a thickness of three feet of low grade siliceous ore, with clay and shale partings. Three or four openings were made along the side of the hill showing about the same thickness of ore. Sample of the ore taken without partings shows 36.36 per cent. iron.

Opening No. 19.—Adam Way land, east side N. E. 1/4, N. W. 1/4, Sec. 9, T. 2 N., R. 3 W. Elevation at base is 625 feet. This deposit at this opening is at drainage level, and is four feet in thickness. The ore is brown on the exposed surface, but within is a blue, conglomerate carbonate, similar to that of opening No. 12. These deposits show a good frontage and the ore will average about 30 per cent.

Opening No. 20.—Located 25 rods east of No. 19. The ore is more siliceous, but in other respects is similar and has about the same thickness.

On the opposite side of the road is another opening near the top of the ridge. The ore is brown and very siliceous.

No drilling was done in this area to determine the backward extent.

Northeastern Field.

Openings 1, 2 and 3.—This opening is thus numbered on account of the length of the face and the series of samples were taken at either end and near the center and over the entire thickness of the ore.

This deposit is located on the Pridemore land, S. W. 1/4, S. W. 1/4, Sec. 1, T. 3 N., R. 3 W. Elevation of base 620 feet, at the top 660 feet, and about 75 feet above drainage. The ore in general is brown, but contains massive blocks which are almost black, and with high metallic luster and of greater purity than the main mass. There are also bands and smaller masses of blue ore.

Core drilling has not yet been done to show the exact extent of this deposit. The dimension determined from exposures are 200 by 1,000 feet and a maximum thickness on the face of 40 feet. These dimensions would give at least 330,000 tons.

This ore is now being shipped to Jackson, Ohio, for the manufacture of ferro silicon, and the reply comes back: ''Keep sending it along; it is good stuff.'' The average analysis of the ore is:

Water	5.31
Silica	49.08
Metallic iron	32.35
Aluminum	1.43
Ferric oxide	46.21
Lime	0.00
Phosphorus	.33
Manganese	.51

This deposit is about 40 rods from the B. & O. S. W. Railroad, from which a track could be laid with little expense, and the ore placed upon the cars from an overhead dump at a very small cost, not to exceed 25 cents per ton.

Note.—The deposit of iron ore on the Pridemore land has recently been sold to the ''Globe Furnace Company,'' at Jackson, Ohio. More than fifty cars of ore have been shipped from this deposit.

Opening No. 22.—Field's land; location same as above. This deposit lies just across a deep ravine east of Nos. 1, 2 and 3.

This has not been developed except by the sinking of a pit from the top of the ridge into the deposit and extending downward into it several feet. The elevation at the mouth of the deposit, near the top of the ore, is 635 feet. The ore is in every respect like that from the above deposit.

This deposit has a frontage of more than 1,000 feet and a backward extent of 450 feet and an average thickness of 20 feet, and a tonnage of 600,000 tons.

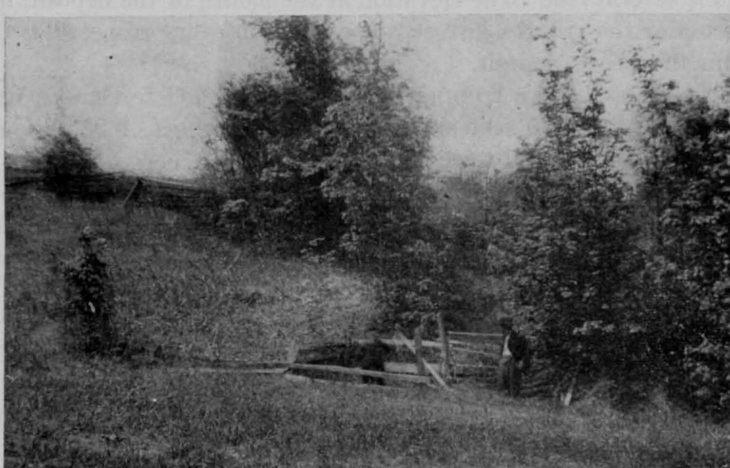
A short extension of tracking, from openings 1, 2 and 3, would reach this deposit and the ore be loaded in a similar way.

Opening No. 21.—In road north of Johnson's schoolhouse large boulders outcrop. No excavations were made to determine the extent, but the deposit here is probably an arm of No. 15 and Nos. 1, 2 and 3, and would be worthy of investigation.

Opening No. 23.—Located on the Dr. Shirly land, center of N. E. ¼, S. W. ¼, Sec. 20, T. 3 N., R. 3 E. Elevation 623.51 feet. On gentle slope, 20 feet above drainage.

Plate XXXIII.

Showing one end of the ore deposit on the Pridemore land. Maximum thickness 40 feet.



Ritter Spring. One of the springs of Chalybeate Water found near the base of the iron deposits.

It is a lens of ore near the surface; it is soft and contains considerable clay. The dimensions are 400 by 180 feet, with a maximum depth of workable ore 9 feet. It contains 25,000 tons, which can be stripped in large part and placed on cars for a few cents per ton. Analysis:

Silica	30.26
Iron	28.28
Alumina	8.60
Ferric oxide	40.40
Calcium oxide	3.10
Phosphorus	.879
Sulphur	.208
Manganese	.573

This ore is too poor to be available under existing conditions. Boring No. 9 will show the thickness of this ore and No. 10 will show that it does not extend back into the hills.

Opening No. 14.—On Thompson's land, 3½ S. W. ¼, N. W. ¼, Sec. 10, T. 3 N., R. 3 W. This deposit lies above the ore of No. 15 and is of small extent and low grade and would only be of value along with the underlying ore. Boring No. 13, 150 feet southwest of opening, penetrated 2 feet of this ore, which at that point was very siliceous and the percentage of iron very low.

Opening No. 15.—Located on Josiah Mundy land, southeast corner S. E. ¼, N. W. ¼, Sec. 10, T. 3 N., R. 3 W. This is only one of a number of openings made in this body of ore. The elevation of the ore at the base of the ore in this opening is 650.56 feet. It is almost at the drainage level. There are four drill holes and four exposures in the deposit. These are indicated on the map and shown on the sections. The chief opening shows a thickness of 12 feet; nine feet of massive blue carbonate capped with three feet of broken concretionary and banded ore. Farther to the north and east the ore outcrops in the bed of the stream with a visible thickness of five feet, and 120 rods to the west five feet of ore is exposed on the bank of the stream, and on the north side of the ridge near the Mundy Spring the ore was found outcropping, but without workable thickness.

Boring No. 11 is 125 feet northwest of the opening and showed 11 feet of ore, with the lower 6 feet massive and the upper five with shale partings as shown in the section.

From the section it will also be shown that about two feet and a half of ore was found a few feet below the main deposit.

Drill Hole No. 9

Formation	Ft.	In.	Ft.	In.
Soil -	2	6	2	6
Soft Red Ore	4	0	6	6
Sandstone	1	6	8	0
Soft Ore-Shale Partings	5	0	13	0
White Shale	13	0	26	0
Blue Shale	12	6	38	6
Ore Lumps	0	8	39	2
Soft Sandstone	11	2	50	4
Iron Ore	1	2	51	6
Blue Shale	10	6	62	0
Black Slate	1	0	63	0
Soft Shale - Gray	2	0	65	0
Sand Shale - w.	16	0	81	0
- Blue Shale	10	0	91	0
Sandstone	20	0	111	0
Sandstone - with Shale Partings	36	0	147	0
Sandstone	18	6	165	6
Limestone	4	6	170	0

Ele. 623.51 Depth 170 Ft.

Dr. Shirley - Land - N.E. 1/4 S.W. 1/4 Sec. 20 T.3. N. R.3. W.

C.W.S.

Boring No. 12, 350 feet northwest of opening and 225 feet northwest of boring No. 11, shows 11 feet 6 inches of ore in the main deposit and nine feet of ore with shale parting and a conglomerate composed of lime, sand and ore. Eight feet of blue shale lies between this and the other deposit. The conglomerate shows 29.75 per cent. iron.

Boring No. 13, 100 rods southwest of holes Nos. 11 and 12, shows 6 feet and 6 inches of the massive ore, with an iron content of 36.05 per cent.

Drill Hole No. 10.

Dr. Shirley-Land- N.E. 14. S.W. 14 Sec. 20. T. 3. N. - R. 3. W. -

Ele. 683.51. — Depth - 125 Ft. -

Formation	Ft.	In.	Ft.	In.
Surface Clay	9	8	9	8
Sandstone -w-	15	4	25	0
Blue Shale with Ore bands	5	0	30	0
" Shale	7	7	37	7
Ore Lumps	0	5	38	0
Blue Shale	45	0	83	0
Soft Sandstone	5	0	88	0
Coal	0	5	88	5
Sand-Shale	2	7	91	0
Soft Sandstone	31	0	122	0
Sandstone - Shale - Partings	3	0	125	0

Plate XXXIV.

Drill Hole No. 11

Ele 686.45 Depth 75 Ft

Josiah Mundy-Land-N.W. 1/4. S.E. 1/4. Sec. 10. T.3. N. R.3. W.

Formation	Ft.	In	Ft.	In
Sandy Soil	4	0	4	0
Yellow Clay	10	0	14	0
White Shale	5	0	19	0
Blue - "	10	0	29	0
Iron Ore	1	4	30	4
Blue Shale	2	0	32	4
Iron Ore	0	8	33	0
Ore & Shale Partings	1	0	34	0
Iron Ore	6	0	40	0
Shale - Blue	0	4	40	4
Coal -	0	9	41	1
Clay Shale-w	8	0	49	1
Iron Ore	0	6	49	7
Ore-Shale Partings	2	5	52	0
Sandstone - w	2	0	54	0
" Brown	1	6	55	6
Soft " white	19	6	75	0

Drill Hole No. 12

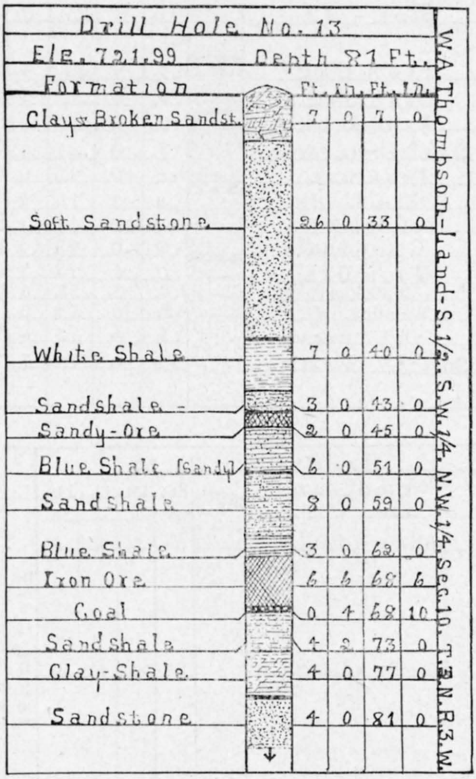
Josiah Mundy-Land- 225 Feet N.W.- No. 11-

Ele. 720.87 - - Depth 94 Ft. -

Formation	Ft.	In.	Ft.	In.
Soil	2	0	2	0
Yellow Clay	5	0	7	0
Soft Sandstone-Br.	34	0	41	0
Blue Shale	11	0	52	0
Blue Shale with Ore	2	6	54	6
Conglomerate - lime Sand & Ore	6	6	61	0
Blue Shale	8	0	69	0
Iron Ore	4	0	73	0
Ore & Shale Partings	2	0	75	0
Iron Ore	5	6	80	6
Coal	0	4	80	10
Clay Shale	4	2	85	0
Sandy Shale	8	0	93	0
Sandstone	1	0	94	0

Boring No. 14, 700 feet north of boring No. 12, is on the edge of the deposit and shows only a slight trace of ore above a few inches of coal with shale partings.

The dimensions from the results of the opening and borings would be as follows: Frontage, 6,000 feet; extent into hill, 1,300

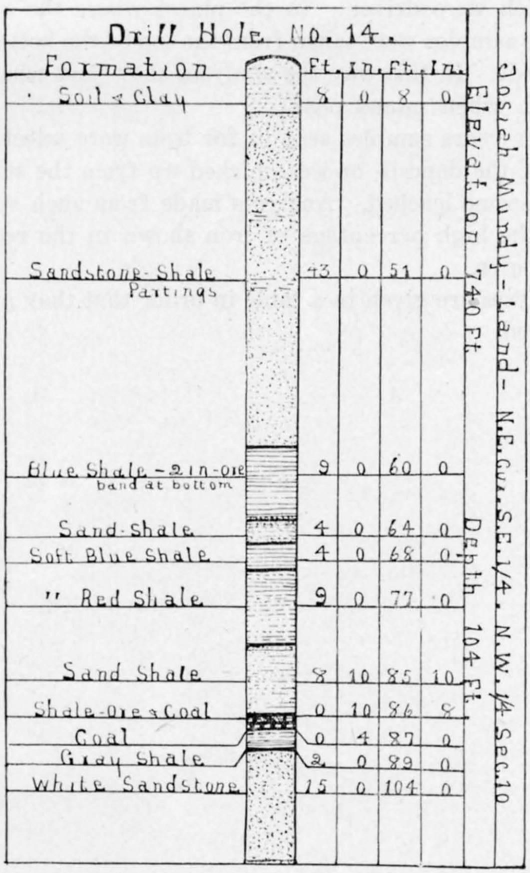


feet, and an average workable thickness of about 9 feet, giving it a tonnage of 4,500,000 tons. The drill left the field without boring a hole to the southeast of the main opening, which would probably have added about a third to the tonnage. The average analysis of this deposit is:

Silica	11.87
Metallic iron	34.79
Ferric oxide	49.30
Sulphur	.757
Lime (CaP)	4.65
Alumina	5.26
Phosphorus	.616
Manganese	.427

A layer of shaly coal, with an average thickness of four inches, is found to be continuous under this deposit.

Opening No. 16.—On McKnight's land, N. E. 1/4, N. E. 1/4, Sec. 17, T. 3 N., R. 3 W. This opening is one of several made in the ore along the sides of the ravine. The ore found in this locality is



concretionary and banded and has shale partings of greater thickness than the ore. The ore would aggregate a thickness of 5 or 6 feet. The ore removed from the shale shows 38.13 per cent. iron. It would be necessary to wash this ore to make it of value in the blast furnace.

This completes the list of the largest ore deposits that have been investigated in the Martin County field. The deposits described would yield a total of more than six million tons of workable ore and the smaller deposits when worked out would probably increase the tonnage about one-half. And the investigation of the yet unexplored area where the same conditions exist would at least double the tonnage of the present field.

Analyses.—The samples for analysis were taken from the faces of the deposits after the excavations had been made, and in the entries which were driven. In the places where the ore was thus exposed the samples were taken from the top of the bottom in a strip one inch wide. In this way the analyses show just what the deposits will run when mined out.

In former years samples sent in for tests were selected from the best part of the deposit, or were picked up from the surface where they had become leached. Analyses made from such specimens account for the high percentage of iron shown in the records of Indiana iron ores.

The analyses are given in a table in order that they may be readily compared.

RECORD OF ORE TESTS.

Number of Opening.	Name of Opening, Sample Mark and Number.	Water. H_2O.	Silica. SiO_2.	Iron Fe. (metallic)	Alumina Al_2O_3.	Ferric Ox. Fe_2O_3.	Lime. CaO.	Phosphorous P.	Sulphur. S.	Manganese Mn.
1, 2 and 3	Huron Bank. Sample No. 1	5.40	44.70	32.20	1.60	46.00		.33		.76
1, 2 and 3	Huron Bank. Sample No. 2	5.30	45.65	32.71	1.20	46.73		.33		.76
1, 2 and 3	Huron Bank. Sample No. 3	5.25	56.90	25.04	15.50	35.72		.22		.00
1, 2 and 3	Huron Bank. Sample No. 4			39.48		56.40				
	Total	15.95	147.25	129.43	4.30	184.85		.88		1.52
	Average	5.31	49.08	32.35	1.43	46.21		.29		.51
4	J. A. Cook Opening. Sample No. 1	10.50	16.90	45.54	4.70	65.07	.85	.65		1.02
4	J. A. Cook Opening. Sample No. 2			32.48		46.40				
4	J. A. Cook Opening. Sample No. 3			40.88		58.40				
	Total	10.50	16.90	118.90	4.70	169.87	.85	.65		1.02
	Average	10.50	16.90	39.63	4.70	56.62	.85	.65		1.02
5	Felton S. Bank. Sample No. 1	9.20	36.50	33.32	4.00	47.60		.54		1.28
5	Felton S. Bank. Sample No. 2		19.84	39.39	11.03	56.27	1.40	.60	.238	.378
5	Felton S. Bank. Sample No. 3		10.64	35.75	4.18	51.07	5.53	.484	.242	.281
	Total	9.20	66.98	108.96	19.21	154.94	6.93	1.624	.480	1.939
	Average	9.20	19.40	35.99	5.84	51.51	3.46	.52	.240	.667
6	Sarah Horner. Sample No. 1			55.44		79.20				
6	Sarah Horner. Sample No. 2	9.20	28.00	38.22	4.50	54.60	1.00	.57		1.53
6	Sarah Horner. Sample No. 3		23.14	36.86	13.00	52.65	4.63	1.03	.140	.438
6	Sarah Horner. Sample No. 4 (at seam)			40.65		58.07		.861		
6	Sarah Horner. Sample No. 4 (away from seam)			41.66		59.51		.919		
6	Boring. Sample No. 5 (12 feet 6in. to 14 feet 6 in.)		22.86	37.87	9.80	54.10	1.60	.882	.016	.666
6	Boring. Sample No. 5 (43 feet 6 in. to 45 feet 6 in.)		9.38	27.32	3.37	39.02	20.00	.244	.087	.846
	Total	9.20	83.38	278.02	30.67	397.16	27.23	4.506	.243	3.520
	Average	9.20	20.85	39.74	7.67	56.75	6.81	.751	.081	.880
7	Stephens (upper ore). Sample No. 1	10.50	26.30	38.82	4.80	55.46	1 05	.46		.76
8	Sarah Horner. Sample No. 1	6.50	11.20	52.22	.80	74.60	2.01	1.00		3.06
8	Sarah Horner. Sample No. 2			50.82		72.60				
	Total	6.50	11.20	103.04	.80	147.20	2.01	1.00		3.06
	Average	6.50	11.20	51.52	.80	73.60	2.01	1.00		3.06

RECORD OF ORE TESTS.

Number of Opening.	Name of Opening, Sample Mark and Number.	Water. H_2O.	Silica. SiO_2.	Iron Fe. (metallic)	Alumina. Al_2O_3.	Ferric Ox. Fe_2O_3.	Lime. CaO.	Phosphorous P.	Sulphur. S.	Manganese. Mn.
9	Wm. Horner. Sample No. 1	8.50	19.80	44.63	5.60	63.76	1.01	.89		.00
9	Wm. Horner. Sample No. 2		25.14	38.63	8.62	55.18	1.80	.753	.754	.384
	Average	8.50	22.47	41.63	7.11	59.47	1.40	.822	.754	.192
10	Gammon. Opening No. 1.									
11	Gammon. Opening No. 2.									
12	Stewart Opening. Sample No. 1		23.52	31.82	4.94	45.46	2.80	.494	.476	.933
13	Johnson. Sample No. 1			42.56		60.80				
13	Johnson. Sample No. 2			51.44		59.20				
13	Johnson. Sample No. 3			45.36		64.80				
	Total			139.36		184.80				
	Average			46.45		61.60				
14	Thompson's Opening. Sample No. 1		23.56	39.89	7.64	56.96	2.33	0.460	.086	.733
14	Boring. Sample No. 13 (43 feet to 45 feet)		14.28	29.84	5.32	42.63	5.99	.273	.324	.561
	Total		37.74	69.73	12.96	99.59	8.23	.733	.410	1.294
	Average		18.87	34.86	6.48	49.79	4.12	.367	.205	.647
15	Mundey Opening. Sample No. 1		6.06	35.85	5.54	51.21	6.78	.708	1.553	.448
15	Mundey Opening. Sample No. 2		11.11	35.35	5.85	50.50	1.30	.406	.799	.446
15	Boring. Sample No. 13 (29 ft. to 30 ft. 4 in.–32 ft. 4 in. to 40 ft.)		14.14	31.36	4.65	44.80	4.80	.478	1.170	.502
15	Boring. Sample No. 13 (62 feet to 68 feet 6 in.)		6.30	36.05	2.74	51.51	7.20	1.099	.521	.354
15	Boring. Sample No. 12 (52 feet to 61 feet)		15.44	29.75	7.71	42.49	3.70	.402	.343	.381
15	Boring. Sample No. 12 (69 feet to 80 feet 6 in.)		18.20	31.56	5.06	45.09	4.10	.604	.156	.430
15	J. B. Loyd. Sample No. 1			36.12		51.00				
	Average		11.87	34.79	5.26	49.30	4.65	.616	.757	.427
16	McKnight. Sample No. 1		22.36	38.13	8.88	54.47	2.20	.629	.087	.416
17	Felton N. Bank. Sample No. 1		26.79	33.94	10.22	48.48	1.80	.633	2.08	.626
18	Davisson. Sample No. 1		30.10	36.36	8.36	51.94	.70	.249	1.37	.466
19	Way. Sample No. 1		44.32	30.81	3.19	44.01	2.80	.323	.552	.650
20	Boring. Sample No. 9 (2 feet 6 in. to 13 feet)		30.26	28.28	8.60	40.40	3.10	.879	.208	.573
21	S. of Road Cor. N. Johnson. S. H			28.84		41.20				

Other Counties.

In Jackson County the shales are mixed with thin bands of earthy carbonate of iron, similar to that found in Clark and Scott Counties. On Hough's Creek, south of Brownstown, the weathered lumps of ore at one time attracted attention, and some parties were induced to undertake the construction of a Catalan forge to work these ores. Some trace of the old mill race yet remains that was dug to secure sufficient fall of water for driving the blast and trip hammer, but the forge was never completed.

In Knox, Vanderburgh, Dubois and Pike Counties, and throughout the coal measures nodules of iron ore are found associated with the coal seams and shales. But these ores are not found in quantities sufficient to be of any economic importance.

Uses of the Indiana Ores.

The Indiana iron ores, as shown by the analyses, are relatively low-grade ores, containing on the average considerable silica, phosphorus, sulphur, etc. These elements, as will be seen, are more or less injurious to the making of first-class iron. However, the presence of these various substances in some classes of iron are very important, and it is especially in such productions that our iron ores can be successfully used.

Sulphur and Phosphorus.—(a) Sulphur, even in very small amounts, has a very injurious effect on wrought iron, making it red-short, although the metal may readily be worked in the cold. With cast iron a small quantity of sulphur is an advantage, making it stronger and more easily fused. Sulphur in pig iron tends to the production of the white variety; the surface and fractured portions often show black particles, which are characteristic of sulphur in iron.

(b) Phosphorus is also very injurious to iron. Even 0.1 per cent in iron is very noticeable; 0.3 per cent in wrought iron makes it harder and somewhat diminished in tenacity; 0.5 per cent. makes it cold-short, but not red-short; 1 per cent. makes it very brittle. Thus the effect of phosphorus on iron is to impart a coarsely crystalline structure, diminish its strength, increase its fusibility and make it cold-short; but on account of its importing fluidity to the metal, its presence is beneficial in making fine castings.

Iron and Silicon.—In early days when a furnace was "going bad," produced what was known as "burnt iron," no founder would use or purchase it, and it was considered a total loss. Later it was discovered that this was simply highly siliconized iron and that it was of great value as a softener. The name "ferro-silicon" was given it and it recently has commanded a premium.

There are several furnaces today producing "ferro-silicon" exclusively, and nearly every stack makes it occasionally. The silica content ranges from 6 to 12 per cent., and the electric furnace produces a still higher grade, running 50 to 75 per cent. or even higher. The manufacture of ferro silicon is considered a healthy branch of the electro metallurgical industry. In Europe, Keller, Leleux & Co. are the chief producers, averaging an output of 250 tons per month. In America the Wilson and Cowls companies are the leading producers.

If iron be heated alone with silica no action takes place. The effect of silica on cast iron is to set the combined carbon free, so that as a rule the greyer the pig the higher the amount of silica.

Ferro Silicon is now quoted at $98@100 per ton f. o. b. export ships Atlantic ports.

Classes of Iron.—The Indiana ores may well be used in the manufacture of iron by mixing with the high grade ores of the north, or they may be used very successfully in the manufacture of ferro silicon. There are several advantages which either use may have. The high phosphorus content of some of these ores is less objectionable when we are informed that southern irons which are being used extensively are high in phosphorus. They rarely contain less than 0.8 per cent. and frequently run higher than 1.5 per cent. From these high phosphorus ores "Off Bessemer" may be made, that is, as the name implies, iron approximating the true, but unfit for steel making. There are no rigid limits set and this iron is popular with carwheel and malleable iron manufacturers.

In designing the classes or grades of iron the former method of inspecting fresh fractures of pig iron to determine the content of silica, sulphur, etc., is being largely replaced by the more accurate method of classification by chemical analysis.

A furnace charging a similar class of ore will usually produce iron carrying nearly uniform phosphorus and manganese, but silica and sulphur vary considerably. These latter elements produce a marked change in the appearance of the fracture, and were it not for furnace conditions and temperature the metalloids could be quite accurately approximated. But under existing conditions the individual judgment of fracture is very much in error.

The various classes of iron may be designated as northern, southern, basic, bessemer, forge, foundry, charcoal and ferro silicon.

The last two classes being comparatively rare, but both commanding a good price in the market.

Furnaces for Smelting Indiana Ores.—The close proximity of the Southern Indiana coal fields, and the increased railroad facilities make Martin and Greene counties admirable locations for blast furnaces, even if the ore should largely be shipped in from other localities.

As stated above, some of the siliceous ore from Martin County is at present being shipped 300 miles to Jackson, Ohio, where it is used for making ferro silicon. Upon investigating the work of the furnaces at Jackson, it was found that ferro silicon was being made very successfully from ores carrying as low as 28 per cent. metallic iron and much of it is taken from deposits less than two feet in thickness. This ore is costing a dollar or even more at the furnace, and they are paying two dollars for the Martin County ore.

If ferro silicon can be made on a paying basis under the above conditions, it would certainly pay a handsome dividend if furnaces for its production were constructed in the heart of the Indiana field. Here the cost of fuel, if brought from the southern field, or coke, if shipped in from distant points, would be about the same as at the Ohio furnaces. But the most economic plan would be the construction of regenerators and gas producers. By this means there would be no doubt about the coals of southern Indiana, including even the local coals, which in these furnaces could be used successsfully. The iron ore could be placed at the furnaces at a cost of 50 cents per ton or even less. Track could readily be laid from furnaces located near Shoals and Bloomfield to the larger deposits and the less and more inaccessible deposits would readily be worked out by the inhabitants and placed at the furnaces or on the cars at a comparatively small cost. By the latter means the tonnage would be greatly increased, since in these smaller deposits each man would be able to mine out several tons per day. The limestone for fluxing is found in contact with some of the ore and at other places it can readily be obtained in great abundance. From the above it is apparent that this ore can be used to advantage in the manufacture of ferro silicon. There is also sufficient timber on the lands to supply all needs in mining operations. As will be seen from the sections of the core drill holes there are large beds of shale in this same region and this shale could be mixed in the proper proportions with the slag from the furnaces, thus producing a good cement. Hence the development of one line of resources will lead to the utilization of other natural products, of which the manufactured products are greatly in demand.

The coming of iron manufacturers into the Indiana field should be encouraged. The reopening of ore deposits, the development of the coal fields, the building of furnaces within the state to smelt northern ores, the building of new railroads, and the extension of others, and the aggressive policy of existing roads to encourage industries along their lines, will undoubtedly again make Indiana a great producer of iron and the other products of commerce that will later be developed.

REFERENCES.

Origin of Ore Deposits:

LeConte's "Elements of Geology."

Van Hise—"Treatise on Metamorphism."

Chemistry of Iron:

Lowthian Bell's "Principles in the Manufacture of Iron and Steel."

Bauerman—"Metallurgy of Iron."

Metcalf—"Manual for Steel Users."

Davis' "Chemistry for Schools."

Lake Superior Region:

Van Hise in U. S. G. S. Reports.

"Wisconsin Geological Survey Bulletin No. 13."

"Engineering and Mining Journal," 1900-1905.

Statistics and Basis of General Information:

"Engineering and Mining Journal," 1900-1905.

"Mineral Resources of the United States," 1900-1905.

"Indiana Department of Geology and Natural Resources," 1869, 1870 and 1875.